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THE ATOM

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BY

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WITH AN INTRODUCTION BY

PROFESSOR FREDERICK SODDY, F.R.S.

INTRODUCTION

By Professor Frederick Soddy, F.R.S.

I HAVE much pleasure in commending to the scientific world this Alternative Theory of Atomic Structure proposed by Dr. Tutin.

He inverts the nuclear type of atom first proposed by Nagaoka and now current in the form known as the Rutherford-Bohr atom, and in his model the electrons form the inner nucleus, with the massive particles circulating in quantized orbits outside. This appealed to me in the first place, because there was in origin no decision possible as to whether the sign of the nucleus was positive or negative.

But in science mere familiarity with a current dogma is so often imputed to it as proof, that there is a considerable danger that the author's theory may not receive the impartial consideration that it deserves, whereas if both alternatives had been put forward from the start there would have been a better chance of evaluating their respective merits and demerits. Dr. Tutin's initial postulate that the very quantum mechanics which make the Rutherford-Bohr atom possible, make also an alternative or

inverted type possible, seems to rest on ordinary common sense. If other advantages follow from the change, the necessary mathematical formulae will no doubt be forthcoming to consecrate the new doctrine and admit it into the established church; for the progress of the times has shown surely, if nothing else, that there is nothing too difficult for the modern mathematician to apply his symbolism to, or failing that, he can always invent a new one for the purpose, even though to most of us he may seem thereby only to make the darkness visible.

As to these other advantages it cannot be denied that Dr. Tutin's theory does seem to single out and group together in an almost uncanny way a number of some of the most important and least understood phenomena of physics and chemistry, phenomena which, like gravity before Newton's day, are so familiar to everybody that they are accepted as though no explanation were necessary and which are totally ignored by theories claiming much more recondite verification.

Now a new idea which does this ought not to be lightly rejected.

It must be remembered that, just because, if it is true, it tells us so much more about the atom than previous theories, it is for this reason much more vulnerable. It would, I think, be asking too much to expect any theory—though here no doubt the

author may disagree with me—at first blush to be able to resolve and reconcile the conflicting specifications of the models necessary to emphasize and depict respectively the physical and chemical properties of the atom, though no doubt ultimately, before it can be implicitly trusted, the model must be able to do so.

In illustration of this it is only necessary to point out that in the Alternative atom the atomic mass no less than the atomic number determines the type of atom assigned, and the mass-structure of the atom produces the chemical character and is accessible to ordinary chemical methods of investigation, whereas this is not the case with its rival. Here the massive constituents of the atom play no part in determining its chemistry, and, indeed, if a model is required to represent the chemical character, the nucleus is invariably left out and regarded as entirely redundant; the whole mass of the atom is relegated to a little central bag of mystery, as inaccessible to common methods of investigation as the centre of a hot star, of which almost anything may be averred, and frequently is, without it seeming to matter very much whether it is right or wrong.

Every chemist must be aware that this is merely an evasion or postponement of the problem, though no doubt convenient when it was originally put forward, whereas what has come to be termed nuclear chemistry, dependent on observation of the dynamics

of single atoms and judicious numerical inferences as to their chemical character, however important, is not really chemistry at all.

So far as Dr. Tutin relies upon support for his theory from the consideration that it reinstates the Law of Causation in the case of radio-active change, the upsetting nature of which the philosophers have somewhat tardily rediscovered, the experimentalist will probably be largely unmoved, however important the matter may seem to the philosopher. In so far as the simple inversion of the ordinary nuclear type of atom is involved, it is hardly to be expected that any direct proof or disproof can be got immediately, but merely a balance of evidence for and against, in which familiarity and convenience may prove important factors. But if in regard to useful practical knowledge the new view provides a working hypothesis where the old theories are worse than useless, it will be assured of a welcome by scientific men.

OXFORD,
    27th February, 1934.

PREFACE

This book is concerned with a problem, a scientific problem, admittedly, but the essential facts are so simple that it is a problem of general interest.

The whole material universe appears to be composed of not more than ninety-two different atoms, the ninety-second atom having ninety-two electrons circulating around its nucleus. Now, as Sir James Jeans puts it: " Atoms having certain definite numbers of electrons, namely 6, 26 to 28, and 83 to 92, have certain special properties which show themselves in the phenomena of life, magnetism and radio-activity respectively . . . the reason resides somewhere in the ultimate laws of nature, but mathematical physics has not yet fathomed it."

More generally, given ninety-two atoms differing from each other only in the number of planets rotating round the central sun, how can we account for their extraordinary differences in behaviour? Is it not possible, perhaps even probable, that the accepted picture of the atom is wrong? We look for an alternative system of construction. We go back to the origin of the Rutherford atom in the

years 1909 to 1913 and we find that an alternative possibility did, in fact, exist, but was completely overlooked. This Alternative atom appears to defy all attempts to prove that it is wrong, in spite of the fact that, as Professor Soddy points out, it is more vulnerable.

In short, we have to decide which atom is real and which is merely an inverted image of reality.

THE ATOM

Two hundred and thirty years ago, Sir Isaac Newton wrote : " The main business of natural philosophy is to argue from phenomena without feigning hypotheses, and to deduce causes from effects, till we come to the very first cause which is certainly not mechanical."

It is clear that Newton believed implicitly in what is known as the Law of Causation, which stipulates that every effect has a cause. Let us try to imagine some event which may be supposed to happen without any cause. For example if a steel test-piece, which ought to fracture at a load of thirty tons per square inch, were suddenly to fracture spontaneously whilst lying on the laboratory table, and if this extraordinary behaviour were repeated by other test-pieces in other laboratories, without any ascertainable cause or reason, the steel industry would shortly cease to exist, and, for some years at least, civilization would come to a standstill.

It is difficult to explain why a breakdown in the Law of Causation should cause less anxiety in pure science than in engineering, but it is a fact that the

behaviour of atoms and electrons can sometimes only be accounted for on the supposition that strict causation no longer holds.   In other words, atoms sometimes appear to behave like test-pieces disintegrating for no ascertainable reason, and several peculiar instances of this irresponsible behaviour are known. It is mainly due to Jeans and Eddington that the apparent failure of causation in atomic physics has been given emphasis.   Thus Jeans writes: " It (the quantum theory) appeared to dethrone the Law of Causation from the position it had heretofore held as guiding the course of the natural world . . . probably the majority of physicists expect that in some way the law of strict causation will in the end be restored to its old place in the natural world.   So far it has not been restored."*

In short, modern science is on the horns of a dilemma.   Either certain conceptions in regard to atomic structure are right and the Law of Causation has failed, or causation holds and the conceptions are wrong.

This situation plainly demands a rigid scrutiny of the origin of the conceptions in question.   We shall find that there is one alternative, and one only, and that this leads us by inevitable steps to a new and extremely simple theory of atomic structure which is strictly governed by causation at every point,

* Jeans, " The Mysterious Universe," pp. 20-29.

and which defines the principal features of atomic behaviour in terms which, though revolutionary in conception, are significant for their agreement with the facts.

Hitherto, atomic models have met with increasing disfavour, and rightly so, because of their inability simultaneously to satisfy the chemist and the physicist. Nevertheless, the *reality* of the atom remains, and there is therefore hope that when the real structure of an atom is known, a model might be visualized which would be acceptable to both chemists and physicists. Therefore, whilst accepting the mathematical interpretations supplied by wave mechanics as to the fundamental nature and behaviour of protons and electrons, we may continue to think in terms of particle mechanics. We must not forget that in the laboratory these units can be weighed and measured, their velocities determined and their tracks photographed.

The fact that it is quite impossible for the human mind to concede any measure of *reality* to the square root of minus one, does not prevent an electrical engineer from forming useful and accurate mental pictures of alternating currents.

It is significant that in 1933 the President of the Royal Society, Sir F. Gowland Hopkins, found it opportune to make the following remarks in the course of his Anniversary Address to the Society:

" The tendency in physics is towards a belief that the Universe is to be described in terms of mathematical relations between unimaginable entities, and some at least have not hesitated to say that in the development of science, the pictorial faculty is proving more and more of a hindrance. . . . With rebellious thoughts in my own mind I was interested when reading Max Planck's fascinating book entitled, ' Where is Science Going? '   In it he, who has done more than anybody to change the scientific outlook, registers afresh his protest against the tendency to deny that the principle of causation holds in nature."

When the President of the Royal Society is a self-confessed rebel against the accepted consequences of modern physics, one is tempted to wonder how many are rebels and how many are loyal.   Since Planck denies that the quantum theory is responsible, it must be the atom, or rather our conception of the atom which is at fault.   It is indeed not difficult to imagine that this might well be.   What could be more unlikely, at first sight, than that ninety elements with their amazing diversity of properties should all be constructed on identical patterns.   They are all supposed to consist of electrons spinning round a nucleus. The material difference between one element and the next is simply one extra electron.   This must explain, for example, the difference between carbon which has six electrons and nitrogen which has seven electrons.

It must explain why some atoms emit light and others do not, why some are electrical conductors and others insulators, why some are magnetic and others non-magnetic. It is perhaps not altogether surprising that whatever the accepted conception of the atom will do, it will not explain these simple matters—and yet they are the first and most fundamental requirements of magnetism, electricity and light.

In his recent book, "The Interpretation of the Atom," Professor Soddy writes: "In any subject, ability to deal only with the recondite and the abstruse, and inability to answer the simplest and most natural inquiries is, to the shrewd observer, perhaps the simplest indication that something of real interest and importance still remains to be found out."

With this in mind, let us see what there may be to find out about the atom.

The relevant facts in regard to the origin of the accepted theory are somewhat as follows:

At the beginning of the present century it was known that atoms were collections of minute electrically charged particles. The negative particles, electrons, were the first to be discovered. Later the positive particles, protons, were identified. They were found to be about 1,850 times as heavy as electrons, but their electrical charge was of the same magnitude, although opposite in sign. Since an

atom must therefore contain equal numbers of protons and electrons if its electrical charge is to be neutral, it follows that the mass of an atom is fairly accurately measured by the number of protons it contains.

In 1909 Lord Rutherford suggested that the atom might consist of a positive nucleus with electrons revolving round the nucleus like planets round the sun.　By 1913 he had carried out experiments which appeared to confirm this view.　He bombarded the atoms of certain elements with alpha particles, and made careful observations of the way in which these minute projectiles were scattered.

These experiments indicated that:

1. Each atom has a nucleus of minute dimensions.
2. This nucleus carries an electric charge characteristic of the element.
3. The angles of scattering are consistent with this charge being either positive or negative.
4. The recoil of the atom indicates that its mass must be concentrated in the nucleus.

Because it was known that the mass of a proton is about 1,850 times the mass of an electron, the experiments appeared to give conclusive evidence that all the protons are in the nucleus, and that the characteristic charge on the nucleus is therefore positive.

In 1913 Bohr, assuming the hydrogen atom to consist of a single proton in the nucleus and a single electron in orbit, was able to calculate the lines of the hydrogen spectrum. In the same year Moseley showed that in proceeding from one element to the next, in the atomic series, the charge on the nucleus increases by one unit. With such swift confirmation, considered in conjunction with Rutherford's scattering experiments, it was natural to assume that the Rutherford hypothesis had been triumphantly substantiated.

Let us, however, examine the position more closely.

We are compelled to admit the validity of observations 1, 2 and 3, because it is inconceivable that we could put any other interpretation on the experimental results. Observation 4 is the only one which is capable of challenge, because it is evident that a very light nucleus rigidly bound to the outer structure of the atom would also react as though the mass of the atom were concentrated in the nucleus. For example, we might satisfy the experimental observation in this respect even if we have nothing but electrons in the nucleus, *provided these nuclear electrons are so firmly bound to the outer atom that the recoil of the nucleus is, substantially, the recoil of the atom as a whole.*

If such rigidity exists, what is its origin? The

answer is not difficult to find.   Using for descriptive
purposes the conceptions of particle-mechanics rather
than wave-mechanics, we know that an electron
moves round the nucleus in a " stable " orbit.   Now
" stability " has no meaning unless it implies the
presence of a restoring force, which will come into
action when there is a small disturbance from the
stable position.

Further, a " stable orbit " has no meaning except
in relation to the distance between the orbit and the
nucleus.   It follows inevitably that whatever con-
strains an electron to remain in a certain orbit in
relation to the nucleus must equally constrain the
nucleus to remain fixed in relation to the orbit.

In this way, quantum laws must endow any
nuclear atom with greater rigidity than it would
possess on the ordinary classical laws, irrespective of
the mass of the nucleus.   Admittedly we do not know
accurately the *magnitude* of this abnormal rigidity;
for our present purpose it is sufficient to know that it
exists and that it opens up the possibility of making
alternative deductions from Rutherford's scattering
experiments, deductions which it would otherwise be
illegitimate to make.

It may seem, at first sight, difficult to accept the
alternative of very heavy masses spinning round a
very light nucleus, but from the purely mechanical
point of view there is nothing impossible in such an

arrangement. On the contrary, a flywheel with a heavy rim and a light hub is a far more commonplace conception than a flywheel with a light rim and a heavy hub. Clearly the essential requirement of such an Alternative atom is rigidity of construction, and we have shown that the quantum theory does in fact impose precisely the type of rigidity which is needed: it constrains the light nucleus or " hub " to remain fixed at the centre of the atom, whilst the heavy outer units still retain freedom of movement in stable orbits round the nucleus. This constraint is, of course, merely a direct result of the operation of Newton's Third Law of Motion, which applies as inevitably to atoms as to other, and in some respects more complicated, mechanisms.

Thus we see that the very laws which rescue the Rutherford atom from a condition of continuous loss of energy by radiation, namely the laws of quantum mechanics, *simultaneously and automatically provide an Alternative atom*, which by the laws of ordinary mechanics would be impossible because it would be quite incompatible with the behaviour of atomic nuclei when bombarded with alpha particles. Thus the Rutherford atom and its alternative are mutually dependant, in the sense that if we admit the possibility of one we are logically compelled to admit the other.

I refer to one alternative, but at first sight there

appear to be several.   Let us examine the general problem of atom building.   We know that we must observe the following conditions:

1. The atom is to contain equal numbers of protons and electrons because we know that ordinary matter is electrically neutral.
2. The number of protons must be equal to the atomic weight.
3. The nuclear charge must be equal to the atomic number.

On the Rutherford hypothesis we have the following further conditions:

4. The protons are all in the nucleus.
5. The number of electrons in the nucleus is equal to the difference between the atomic weight and the atomic number.
6. The number of electrons outside the nucleus is equal to the atomic number.

Thus knowing the atomic weight and number, we can write down immediately the distribution of protons and electrons in a Rutherford atom, e.g. carbon:

Atomic Weight . . .	12
Atomic Number . . .	6
Protons in Nucleus . . .	12
Protons outside Nucleus . .	0
Electrons in Nucleus . . .	6
Electrons outside Nucleus . .	6

If, however, we are no longer compelled to place all the protons in the nucleus, whilst still observing conditions 1, 2 and 3, we have the following possibilities:

Protons in Nucleus .	0	1	2	3	and so on up
Protons outside Nucleus .	12	11	10	9	to 12 protons
Electrons in Nucleus .	6	7	8	9	in nucleus.
Electrons outside Nucleus	6	5	4	3	

In general for a given element, the total number of possible arrangements is equal to $(W + 1)$ where W equals the atomic weight, and thus with 92 elements, there are theoretically a large number of different ways in which the protons and electrons may be arranged.

Let us see if, by examining the boundary conditions, we can find a clue to the system adopted.

In the case of hydrogen we have nominally two alternatives.

(a) 1 Proton in the nucleus.
    1 Electron outside the nucleus.

or

(b) 1 Electron in the nucleus.
    1 Proton outside the nucleus.

These are seen on inspection to be identical—because the atom as a whole will in each case rotate about the common centre of gravity of the system.

For the next element, helium (atomic weight 4, atomic number 2), we have 5 alternatives.

Protons in Nucleus	.	0	1	2	3	4
Protons outside Nucleus	.	4	3	2	1	0
Electrons in Nucleus	.	2	3	0	1	2
Electrons outside Nucleus		2	1	4	3	2

Now apart from hydrogen which, as we have seen, is a unique case, helium is the only element for which we have positive information as to the number of electrons outside the nucleus. Evidence from spectroscopy, radio-activity and positive rays indicates that helium has only 2 outer electrons. We now see that there are only two systems of arranging the protons and electrons which give this result for helium:

1. With all the protons in the nucleus.
2. With all the protons outside the nucleus.

If we were to build up a series of elements on any of the other alternatives, we should get a construction for helium which we know to be against the facts of experimental evidence, and consequently we must eliminate all possibilities with the exception of these two.

The former is the Rutherford-Bohr atom. The latter we shall refer to as the Alternative atom. Incidentally we may note that these are the two simplest systems of constructions, the mass of the atom being either all in the nucleus or all outside it.

It is important to note that the Alternative system does not imply that in the case of one proton and one electron, the proton rotates about the electron. This would, of course, be a mechanical impossibility even with the aid of quantum-rigidity. It does, however, stipulate that *two* protons may rotate about *one* electron, in fact it seems inevitable that the nucleus of heavy hydrogen forms such a unit.

Let us now compare these two systems of construction.

RUTHERFORD-BOHR SYSTEM

Atomic Number	Atomic Weight	Atom	Protons in Nucleus	Electrons in Nucleus	Electrons outside Nucleus
1	1	Hydrogen	1	0	1
2	4	Helium	4	2	2
3	7	Lithium	7	4	3
4	9	Beryllium	9	5	4
5	11	Boron	11	6	5
6	12	Carbon	12	6	6

ALTERNATIVE SYSTEM

Atomic Number	Atomic Weight	Atom	Electrons in Nucleus	Protons outside Nucleus	Electrons outside Nucleus
1	1	Hydrogen	1	1	0
2	4	Helium	2	4	2
3	7	Lithium	3	7	4
4	9	Beryllium	4	9	5
5	11	Boron	5	11	6
6	12	Carbon	6	12	6

We note that if our object is a *systematic* variation of the nucleus, we should adopt the Alternative system, but if our object is a systematic variation of the outer structure, we should adopt the Rutherford-Bohr system.   Now we know that there is a systematic variation of the *charge* on the nucleus—this is provided for by each system, though in a curiously different manner.   It is not so evident that there is a systematic variation of the outer structure, in fact the chemical and physical properties of the elements, although certainly periodic, do not reveal any deliberate attempt to secure consecutive variation in properties from one element to the next.

Let us now consider the mechanism whereby one atom may attach itself to another atom, either of the same kind or of another kind.   If we were instructed to devise a means for uniting two identical free systems, each consisting of a minute electrically charged core, with minute electrically charged particles spinning round it at high speeds, how should we proceed?   We may attempt to interlock the two systems in some way, or we may attempt to set up a force of attraction between them.   Both types of atomic union must be possible if the facts of chemistry and electro-chemistry are to be explained by the Rutherford-Bohr atom.

We must not, however, overlook the fact that the mechanical aspect of the problem is not solved merely

by providing atom A with a means whereby it may unite with atom B. The mechanism must be automatic, it must be self-activated. In short, atoms must be endowed with both the urge to unite and the means for doing so. Nature is faced with a similar problem in reproduction.

Can we legitimately claim that our present conceptions of atomic union are logical in this sense? They are decidedly *illogical* if we insist that the Law of Causation shall be obeyed. It is easy to see that two neutral atoms will be attracted to each other if one has lost an electron and another has captured one, but the cause of this tendency to gain or lose electrons appears to be unidentified if not unidentifiable. Similarly, it is equally difficult to find a cause for the tendency of neutral atoms to share electrons. It may be that there are latent and obscure forces acting of which we are ignorant, or it may be that atomic union does not occur in this way.

If we adopt the latter view, we must arrange to endow all atoms which are capable of union with both the means and the urge to unite, so as to comply strictly with the Law of Causation. On examining this problem we see that, short of invoking new phenomena, we must provide an electro-magnetic linkage. We must equip a monovalent atom with one electro-magnetic link and a bivalent atom with two such links, and so on. If we can conceive an

atom so equipped, we see at once that it has, inherent to its structure, the necessary mechanism for self-activated union.

How can we provide such an ideal mechanism? In the case of the Rutherford-Bohr model, the problem is evidently one of some difficulty. Consider, for example, a monovalent atom such as sodium. We should have to arrange the electron orbits in such a way as to develop a resultant electro-magnetic field. It would appear, however, that any arrangement of this nature would necessarily provide bivalent linkages. Consequently with the orthodox atom this fundamental question of uniting atoms brings us to an impasse. If we provide the means to unite we cannot find an urge, and if we provide the urge we are not in possession of the correct means.

Let us turn now to the Alternative atom, and apply similar tests. In order to do this we shall have to consider in more detail the consequences of an inverted atomic structure of this kind. If W is the atomic weight and N the atomic number, we have in general N electrons in the nucleus, and W protons outside the nucleus. We must also have $(W - N)$ electrons outside the nucleus. Since these extra-nuclear electrons are repelled by the nucleus, they can only be tied to the atom by attaching themselves to groups of protons, always provided that the resultant charge on the group remains positive, so as to main-

tain a resultant attraction between the group and the nucleus. Thus all the possible groups containing not more than 4 protons are as follows:

Symbol	Group	Resultant Positive Charge
p	One proton . . .	1
b	Two protons and one electron .	1
c+	Three protons and one electron .	2
c−	Three protons and two electrons	1
d+	Four protons and one electron .	3
α	Four protons and two electrons .	2
d−	Four protons and three electrons	1

For purely tentative purposes we will assume that the maximum number of protons in a group is 4, and consequently the above list represents all the permissible combinations.

Let us see how we can build up structures representing the atoms of the 92 elements, using these constructional units in such a way as to represent the known chemical and physical properties of each element.

The most direct method of approach to this problem is to consider the nature of the 6 inert elements, helium, neon, argon, krypton, xenon and radon. We know that these atoms do not unite with other atoms, and consequently we must consider how we can deprive them of the mechanism for union with which other atoms are endowed.

In the case of the Rutherford-Bohr atom, this

problem was dealt with in a manner which was at least self-consistent although it involves some remarkable assumptions. Rydberg pointed out that the atomic numbers of the inert elements could be represented by the series $2\left(1^2 + 2^2 + 2^2 + 3^2 + 3^2 + 4^2\right)$ taken to the necessary number of terms. Thus in proceeding from one inert element to the next, we increase the number of outer electrons by $2n^2$ where n is an appropriate integer. We deduce from this that $2n^2$ gives a " stable " group of electrons, that is a group which resists the addition or removal of electrons. This is necessary in order to make the inertness of these elements consistent with the idea that chemical union is achieved by exchanging or sharing electrons. The position is that we have to assume that the number $2n^2$ possesses this mysterious property. We must further assume that when $n = 2$ the stable properties of the function $2n^2$ attain a maximum value, irrespective of the charge on the nucleus. This procedure is not very satisfactory from the scientific point of view, however well it may appear to interpret observed facts.

For the Alternative atom, we are logically compelled to stipulate a more positive mechanism for chemical union, and this difference in mechanism requires a different method of securing the inertness of an element. Obviously, if electro-magnetic resultants are the only means by which atomic union can

be reconciled with causation, we must, in an inert atom, take steps to ensure that there are no such resultants. This can only be done by providing the maximum degree of symmetry.

In the case of helium, we must therefore arrange the 4 protons in 4 equidistant orbits.

To construct the next inert atom, we retain these 4 protons as a core, and arrange 4 alpha units in 4 equidistant orbits. This gives us neon (20).

Retaining the neon structure, we place 4 more alpha units in equidistant orbits. This gives us argon (36).

This process is continued on the lines shown in the table below:

Inert Atom	Arrangement of Protons		Total Number of Protons
Helium (4)	4	=	4
Neon (20)	$4 + 1 \ (4 \times 4)$	=	20
Argon (36)	$4 + 2 \ (4 \times 4)$	=	36
Krypton (84)	$4 + 2 \ (4 \times 4) + 3 \ (4 \times 4)$	=	84
Xenon (132)	$4 + 2 \ (4 \times 4) + 6 \ (4 \times 4)$	=	132
Radon (228)	$4 + 2 \ (4 \times 4) + 12 \ (4 \times 4)$	=	228

Thus we see that we can provide the inert gases with the requisite symmetry, and further, the units of which they are composed are all helium atoms. Consequently, if we get no resultant field from a helium atom, we should get no resultant field from these alpha units. In other words we must regard an alpha unit as inert.

The isotopes of the above atoms may be obtained

by placing single protons in orbits as close to the nucleus as possible, so that their electro-magnetic field is screened by the outer structure. Thus neon (22) is obtained from neon (20) by adding two protons close to the nucleus, the inertness of the outer structure being substantially unaffected.

It is legitimate to inquire why the principal isotope of argon should be 40, instead of 36 as one might expect from the above, but 36 is undoubtedly the *normal* isotope. Similarly the principal isotope of radon is 222, but it is admittedly difficult in our present state of knowledge to explain, on any atomic theory, the different intensities of the isotopes of an element, but this does not mean that the explanation is Fate. We also see that the process by which the inert structures are expanded is not continuous, although there is no reason to suppose that the primary conditions of symmetry are not fully maintained.

If we compare this system of constructing inert elements with the corresponding method for the Rutherford-Bohr atom, we must recognize that the latter is founded on an *ad hoc* assumption as to the " stability " of the numbers 2, 8, 18 and 32, whereas the former is directly derived from the application of the Law of Causation to the problem of atomic linkage.

We may now proceed to consider the structure of atoms which are not inert. From the known

chemical behaviour of helium we have deduced that an alpha unit must be regarded as an inert unit. Further, we shall make the tentative assumption that any single protons which may be used as constructional units are placed near the nucleus, and play no part in atomic union.

This leaves us with the 5 groups or units which we have denoted by the symbols b, c^+, c^-, d^+ and d^-. With these 5 kinds of unit we must interpret the valency characteristics of each element. We must also attribute the linking ability of these valency units to the resultant electro-magnetic field which they are capable of setting up.

Now let us consider a simple element such as lithium. We know that the principal isotope contains 7 protons. We know that the nuclear charge is 3. We know that lithium is a metal, and we must therefore make provision for electrical conductivity. We also know that the lithium atom is monovalent, and consequently its mechanism for chemical union must provide only one link, and therefore only one valency unit. Further, when lithium is bombarded with alpha particles, it appears that no single protons are ejected. Consequently its structure must contain no isolated protons.

Now there is only one way in which the lithium atom can be constructed so as to fulfil these requirements. We must give it a c^+ valency unit to provide

for its monovalent chemical properties, and we must give it an alpha unit to complete the requisite number of protons. It must have 3 electrons in the nucleus, to give the correct nuclear charge. Let us tabulate this:

	Electrons			Protons
In nucleus .	. 3	In nucleus .	. 0
α unit .	. 2	α unit .	. 4
c^+ unit .	. 1	c^+ unit .	. 3
Total Electrons	. 6	Total Protons	. 7

We see that in the lithium atom so constructed there are 7 protons and only 6 electrons, and therefore the atom will attract to its vicinity a single electron. This electron is not bound to the atom in the same way as the other electrons in the atom. The electrons in the α and c^+ groups, though not directly bound to the nucleus, are bound to their respective units. The odd electron is bound to neither. If the atom could otherwise be made electrically neutral, it would not be required. It so happens, however, that this odd electron is most useful. The principal property of a metal as distinct from a non-metal is the facility with which it conducts electricity. Now it has been proved conclusively that the phenomena of electrical conductivity are due to " free " electrons, which are known to exist in metals in large numbers. We shall later

discuss in more detail the difficulty of providing these free electrons on the Rutherford-Bohr hypothesis. Here, as we see, the free electrons are automatically provided for us.

It is not difficult to see that these " free " electrons are very loosely tied to their respective atoms, since they are actually repelled by the nucleus and may therefore be easily set in motion by electrical forces.

In passing we may note that lithium has an isotope of mass 6, and thus we can write the outer structures of lithium atoms in the form

$$\text{Li}^6 = a + b$$
$$\text{Li}^7 = a + c^+$$

We may construct the atoms of beryllium and boron in a similar manner. Thus beryllium has 4 electrons in the nucleus, and 9 protons outside the nucleus, is bivalent, has metallic properties, and the atom apparently contains no isolated protons. Hence for beryllium we may write

$$\text{Be}^9 = a + c^+ + b$$

In the case of boron, we must have 5 electrons in the nucleus and 11 protons outside the nucleus, with 3 electro-magnetic valency units. Boron is a very good electrical conductor at moderate temperatures (500° C). Protons are released from boron atoms under bombardment by alpha particles. When bom-

C

barded by protons, boron appears to disintegrate into 3 alpha particles. The constitution of boron must therefore be represented by

$$B^{11} = 2p + 2c^- + c^+$$
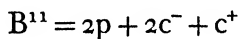
The step from boron to carbon on the orthodox theory amounts to nothing more than a slight increase in the nuclear charge, and one extra outer electron. This nevertheless produces the most astonishing change in atomic properties, whilst if we proceed to the next element we get an even more astonishing change.

What data have we from which to determine the Alternative structure of carbon. We must have 6 electrons in the nucleus, and 12 protons in the outer atom. Carbon is a non-metal, is quadrivalent, and Rutherford was unable to eject protons from it. Thus carbon might be $\alpha + 4b$. This is at least a possibility. If we try $4c^+$, we should have an atom with a total of 12 protons and only 10 electrons. This would necessitate 2 free electrons per atom, with the result that carbon if so constituted would be a metal. If we try $4c^-$, we have a total of 12 protons and 14 electrons. Thus in order to make the atom electrically neutral, we should require to attract 2 free " positive " electrons. Free protons will not serve because the atomic weight of carbon would then be 14. Positive electrons have been detected,

but the evidence appears to indicate that they are not normal units of atomic structure, consequently we will exclude for all atoms the possibility of an excess of electrons over protons. In the case of carbon, positive free electrons would give the element metallic properties quite as effectively as negative free electrons, so we cannot admit the possibility of the structure being represented by $4c^-$. For the foregoing reasons we must also reject $(3c^+ + c^-)$ and $(3c^- + c^+)$. Also, combinations such as $(2p + 2b + 2c^+)$ and $(2p + 2b + 2c^-)$ are inconsistent with the fact that no single protons have ever been ejected from carbon atoms. Thus by a process of elimination, we deduce that the structure of carbon must be either $(a + 4b)$ or $(2c^+ + 2c^-)$, because these are the only combinations of units which satisfy our requirements. Since Sir J. J. Thomson was able to obtain " 3-mass " units from carbon under electron-bombardment, there is a balance of evidence in favour of $(2c^+ + 2c^-)$.

Nitrogen has a maximum valency of 5 but a " principal " valency of 3. We may interpret this by assuming that nitrogen has 3 valency units of one kind and 2 of another kind. Bombardment observations show that nitrogen must have at least one proton. Again we find only one formula which will satisfy the conditions, namely $(p + 3c^+ + 2b)$. This implies that the nitrogen atom attracts 2 free electrons, and thus nitrogen must have semi-metallic

properties. It is a curious fact that solid nitrogen is highly photo-electric, whereas solid oxygen is not.

In a similar manner we can arrive at expressions to represent the structure of all the elements, but in many cases we find that there are legitimate alternatives, and the correct one may only be determined by more elaborate methods of deduction. On reference to the accompanying table, formulae for the structure of the majority of elements will be found, but in certain cases these must be regarded as provisional only. Note that for chemical purposes we are not concerned with the " inert core " of the atom, and thus we can omit these terms from valency expressions. For example, we may express the valency of nitrogen by $3c^+ + 2b$ and of chlorine by $c^- + 7b$.

In this way we can complete the process of equipping each atom with the appropriate mechanism for effecting chemical combination. These conceptions only require a single type of linkage, whereas with the orthodox atom, at least two distinct types are recognized, namely electro-valency and covalency. The former is characterized by one atom losing an electron which is captured by the other. The latter is characterized by electrons being *shared* between two atoms. Thus in the first case the atoms are ionized whilst in the second case they remain neutral.

Is it possible for the single valency mechanism of the Alternative atom to interpret these observed differences in the electro-chemical behaviour of elements, indicating the apparent existence of two different types of linkage? This can best be answered by considering a typical electro-valent union such as NaCl. On the orthodox theory the sodium atom loses an electron and becomes a positive ion whilst the chlorine atom gains one and becomes a negative ion. On the Alternative theory, the " b " unit of the sodium atom establishes an electro-magnetic link with the " c^- " unit of the chlorine atom. The sodium atom has a free electron, which is disturbed by the act of union and transfers itself to the chlorine atom. Hence the ionization. It follows, however, as a logical consequence of this argument that chemical ionization is only possible when at least one of the combining atoms possesses free electrons. Since our structures for carbon,* oxygen, silicon and sulphur do not provide these elements with free electrons, such atoms cannot play a primary part in ionization, and if chemical ionization occurs, they must always form negative ions, since they cannot possibly form positive ones. This is exactly what happens. It is inevitable on the Alternative theory, whereas on the orthodox theory it is difficult to find a convincing explanation for the fact that some atoms

* C^{12}, O^{16}, Si^{28}, S^{32}.

part with electrons easily, some reluctantly, and some not at all.

Thus not only have we a simple explanation for the apparent existence of two types of chemical combination, but this simultaneously provides an explanation of the anomalous distribution of ionization properties amongst the elements.

Let us concede in view of the foregoing, that there is no reason to suppose that the Alternative atom should not at least be capable of interpreting chemical phenomena as readily as the Rutherford-Bohr atom, and possibly with less ambiguity.

Will the Alternative theory be equally successful in interpreting the phenomena of light? Bohr's brilliant calculation of the hydrogen spectrum was so remarkable in its apparent vindication of Rutherford's conceptions of atomic structure that it might well discourage any subversive mind seeking a fundamental flaw in the origin of those conceptions. Further, the Bohr theory of spectra has, with minor extensions, proved of great service to spectroscopists in the ordering of the spectral lines of all the elements. It may seem inconceivable that the atomic model on which rests so much intricate verification of theory by observation, may require to be turned inside out. It will be even more remarkable if this inversion of the foundations should leave the superstructure practically untouched.

Under suitable conditions every element will yield an emission spectrum, which is equivalent to saying that every element, if sufficiently stimulated, will emit light. The science of spectroscopy has proved beyond question that the line spectra of atoms are due to the excitation of an " optical electron," that is an outer electron which effects a partial escape from the field of force of the atom, and which, on its return, radiates energy. At first sight it w ___ seem that since all the elements have a line spectrum, they must all have at least one outer electron, thereby showing that the Alternative theory is wrong, because in the case of carbon, oxygen, silicon and sulphur there are no free electrons, except for the higher isotopes of these elements, which are only present in small percentages. However, it is a remarkable fact that these are the very elements whose spectrum it is most difficult to excite under conditions which permit other elements to give a brilliant spectrum. For example, carbon, oxygen, silicon and sulphur give no flame spectrum, whereas one-thousandth of a milligram of calcium or one-millionth of a milligram of sodium can readily be detected in a flame. Sulphur is supposed to have 6 outer electrons, and the calculated energy required to remove one of these is only a few volts more than that required to remove one of the 2 outer electrons of calcium. But whereas a low temperature flame will easily excite the calcium electrons, the

sulphur electrons refuse to move, nor will they move in an electric arc.   Surely this is not inconsistent with the suggestion that the 6 outer electrons of sulphur do not really exist, and that the 2 observed outer electrons of calcium are the 2 free electrons which are required on the Alternative theory to complete the structure of that element.

This appears to be a point which modern spectroscopists have not stopped to explain, and it is possible that they have regarded it as a matter which ought to be referred to the chemists.   Thus the fundamental fact that some atoms emit light, whilst others do not, remains without any attempt at interpretation.

Sulphur and oxygen are only two of several elements which have 6 outer electrons, but they are the only members of Group 6 which display this extreme resistance to providing illumination, and in the case of sulphur in particular, it would be of very great importance to the steel industry if someone could devise a method capable of detecting spectroscopically the presence of sulphur in iron.   It is one of the few elements which defy such detection, and unfortunately even a small quantity is apt to have very serious consequences on the physical properties of the metal.

The lines of carbon and silicon in the iron spectrum are relatively not very pronounced or

numerous, and this fact is explained on the new theory on the basis that only the higher isotopes are effective. At present, it would seem that this can only be tested qualitatively, but the differences between one atom and the next are frequently so striking that quantitative comparisons are almost unnecessary.

Consider, for example, nitrogen and oxygen. When these gases are placed in an electrodeless discharge tube and excited under identical conditions, the former is highly luminous and the latter almost non-luminous, to such an extent that a very small trace of nitrogen mixed with the oxygen as an impurity, will " swamp " the oxygen spectrum. In general the spectrum of oxygen is peculiar in that it does not show up clearly in the presence of other gases. On the Alternative system all the gaseous elements, with the exception of oxygen, have free electrons associated with the principal isotope.

Curiously enough, nitrogen actually has a higher ionization potential than oxygen, that is a higher voltage is required to remove an electron from a nitrogen atom than from an oxygen atom.

In general, every element has at least one isotope which, on the Alternative theory, has one or more free electrons associated with a positively charged atomic " core."

Under heavy electronic bombardment, further electrons may be released from the valency units, and the reader who is interested can satisfy himself that in this way the spectra of stripped atoms, for example Li_I, Be_{II}, B_{III} and C_{IV}, can be adequately interpreted.

This gives the spectroscopist a mechanism which, for his particular purpose, is equivalent to that which he at present pictures, namely an excited electron, radiating energy from the field of a singly, doubly, trebly or quadruply charged atom. As we have seen, it is more helpful than his orthodox picture, because, whilst preserving his quantitative explanations of the occurrence and non-occurrence of spectral lines, he can now account for the existence or non-existence of the spectrum itself.

From the philosophical point of view, this interpretation of the origin of light is of special significance. We have shown how Alternative atoms may be constructed which are able and anxious to link up with other atoms, thereby providing an auto-activated means whereby an infinite variety of substances may achieve existence, assuming unlimited supplies of protons and electrons, and it is obvious that a series of elements could quite easily be constructed without any free electrons. For example, lithium, sodium, potassium and so on might have had atomic weights exactly double their atomic numbers. The result,

however, would be a universe without light. There would therefore be chemistry but no life. Is this an accidental state of affairs, or must we suppose that the atomic weight is always more than double the atomic number because of the *necessity* for light? With the Rutherford-Bohr atom it would be quite logical, even inevitable, to conclude that the existence of light is accidental, because optical electrons do not, in this case, have to be specially provided; consequently the action of light rays on certain chemical substances is a purely accidental phenomenon, and thus life itself is accidental.

It is therefore not surprising to find a modern physicist (Sir James Jeans) writing: " Chemistry suggests that, like magnetism and radio-activity, life may merely be an accidental consequence of the special set of laws by which the present universe is governed."* This illustrates the inevitable consequences of an atomic model which does not obey causation laws, and which, when faced with inexplicable phenomena, invokes " Fate." A further passage from Jeans will illustrate this more clearly:

" It is known that the atoms of radium, and of other radio-active substances, disintegrate into atoms of lead and helium with the mere passage of time, so that a mass of radium continually diminishes in

* " The Mysterious Universe," p. 10, Jeans.

amount, being replaced by lead and helium. The law which governs the rate of diminution is very remarkable. The amount of radium decreases in precisely the same way as a population would if there were no births, and a uniform death-rate which was the same for every individual, regardless of his age. Or again, it decreases in the same way as the numbers of a battalion of soldiers who are exposed to absolutely random undirected fire. In brief, old age appears to mean nothing to the individual radium atom; it does not die because it has lived its life, but rather because in some way Fate knocks at the door."

The spontaneous impulse which results in a particular atom suddenly deciding to disintegrate now, rather than next year, or a hundred years hence, is most disconcerting. The phenomenon is invariably cited by the positivist school as a typical example of an event without a cause—as a case where Fate defeats causation.

If we examine the problem more closely, we see that the dilemma is due not to the incidence of a statistical law, but to the fact that the law appears to have no possible origin. In the case of a population with no birth-rate and no death due to old age, every individual has at a given moment an equal chance of death, exactly as for an atom of radium. There is

a profound difference, however, between the two analogies. For the individual, death may come from war, pestilence and famine, or from any of the many hazards of existence; but for the radium atom, to what hazards is it exposed? It is as though in the community pictured by Jeans, every coroner's jury returned the same verdict: "Death from unknown causes." Would not such a community rapidly come to regard death as a phenomenon for which the word "cause" ceased to have an intelligent meaning? This is precisely the position we are in after holding innumerable inquests on the death of atoms of radium.

The interior of the nucleus of a Rutherford-Bohr atom is the most impregnable place in the physical world. We cannot conceive any outside influences which could account for the observed disintegration, nor can we conceive what influences there may be within the nucleus itself, which might result in a characteristic chance of an internal accident, the probability of which is to be the same for each atom of a given element, but different for other elements.

Now it is evident that the natural method of attacking this impregnable fortress is to bombard it. This we proceed to do with high velocity shells in the form of alpha particles. Does the nucleus disintegrate? Yes! But in the most astonishing manner. Instead of ejecting an alpha particle it

ejects—a single proton! What is more it captures our projectile.

Perhaps we can clear up some of these perplexities.

On the Alternative system the heavier atoms are required to have a specified number of alpha particles rotating about the nucleus. Now the orbits of the alpha particles are not necessarily circular. On the contrary it appears that outer orbits tend to become highly elliptical. An elliptical orbit, in particle-mechanics, implies that the nucleus is at one of the foci of the ellipse, and hence as the orbit becomes more highly elliptical, the path of the alpha particle gradually comes closer to the nucleus. For the orthodox atom, both the nucleus and the orbital electrons are so small compared with the dimensions of the orbits, that they may be regarded as point charges. Thus it is inconceivable that an orbital electron could ever hit the nucleus about which it rotates.

With the Alternative atom, the alpha particle cannot possibly be regarded as a point charge in the same way as a single electron might. Consequently if we continuously increase the ellipticity of the orbit, we must inevitably reach a limit at which the alpha particle is on the point of hitting the nucleus.

The orbit cannot be absolutely constant, but must fluctuate, however slightly, about its mean position of quantum-stability, just as a floating body oscillates

about its axes of statical stability. Under such con-
ditions, as the ellipticity of the orbit is increased,
the chance of an alpha particle hitting the nucleus
becomes first appreciable and ultimately large, the
frequency of this event being controlled by the laws
of probability. Thus for each radio-active atom we
have a characteristic probability of an alpha particle
being ejected at any given moment. This is exactly
what we need in order to account for the observed
facts.

It will be necessary to investigate this mechanism
in greater detail, but for the present we may draw
attention to the fact that this kind of action, though
governed by statistical laws, is also most definitely
subject to the Law of Causation. It is obviously not
a case of " Fate knocking at the door," to quote the
phrase used by Sir James Jeans to describe the radio-
active mechanism of an orthodox atom.

Consequently it destroys one of the main props of
the " No Causation " school of thought.

In 1933 the controversy between the Causation
scientists, headed by Planck and Einstein, and the No
Causation scientists, lead by Eddington and Jeans,
reached a critical stage. The position is crystallized
in the following remarks of Einstein : " If I say that
the life span of an atom is indetermined in the sense
of not being caused, then I am talking nonsense. . . .
I am entirely in agreement with Planck. . . . He

admits the impossibility of applying the casual principle to the inner processes of atomic physics *under the present state of affairs.*" (The italics are mine.)

Nevertheless, so long as we have no constructive alternative to the theory which Eddington and Jeans have so boldly pursued to its illogical conclusion, we must concede that for the moment they hold the field.

And so this apparently insignificant question of the life-span of an atom of radium may be the fulcrum on which hinges both the past and the future of physical science.

If the Alternative system of atomic structure is to be consistent, it must automatically provide a mechanism for radio-active disintegration which will be governed not by " Fate," but by causation at every point.

Therefore, from the point of view of strict causation, we must now ask, " What disturbing forces could produce the orbital perturbations which are essential in order to introduce the element of probability into the phenomenon ? " This would be difficult to answer if we had a single alpha particle rotating round the nucleus, but for an actual atom of radium there are 53 other alpha particles, each of which is rotating in a different orbit, and each tending to produce a small perturbation in the orbit of the

particular alpha particle which we are considering.
Further, each of the 54 alpha particles has a
characteristic speed of rotation, and thus they are
weaving round the nucleus a constantly changing web
of orbits, and any particular pattern at any given
instant will have a mathematical probability of
recurrence within a definite period of time. It
follows that an alpha particle which experiences a
maximum perturbation at a given instant, may
expect to receive *exactly* the same perturbation at
some future date.

From this point of view we see that any exceed-
ingly small but finite amplitude will serve our
purpose. As soon as we make the amplitude zero,
as it would be for an atom consisting of a nucleus
and a single alpha particle, the probability of the
particle hitting the nucleus can have only one of two
values, zero or one hundred per cent.

Now if we consider a given quantity of a radio-
active element, it is evident from the mechanism we
have described above, that since all the atoms are
identical, they will all have an equal chance of
" death " at any particular moment. Further, the
" death-rate " will be strictly proportional to the
quantity of the element present.

For any other radio-active element, the same
law will apply, but the characteristic probability,
measured in terms of the half-value period, will be

D

different for each element, due to their different outer structure.   For example:

Element	alpha Ra↗→	alpha Rn↗→	alpha RaA↗→	alpha RaB↗→	beta RaC↗→	beta RaC¹↗
Atomic weight	226	222	218	214	214	214
Atomic number	88	86	84	82	83	84
Half-value period	1600 yrs.	3·83 days	3 min.	26·8 min.	19·7 min.	10^{-6} sec.

As the normal path of the operative alpha particle becomes more and more highly elliptical, thereby approaching the nucleus more closely, the half-value period should rapidly diminish, because, *ex hypothesi*, and if the ellipticity is increased continuously, the point will be reached at which the nucleus will be hit once per revolution and the half-value period would then be zero.   Thus the occurrence of such an infinitesimal figure as that for RaC¹ is not surprising.

We must now consider that remarkable law discovered by Soddy, the Displacement Law of Radioactive Change: an atom which emits an alpha particle moves two places to the left in the periodic table, and an atom which ejects an electron, i.e. a beta particle, moves one place to the right.   In other words, an alpha change reduces the atomic number by two units and the atomic weight by four units; a beta change *increases* the atomic number by one

unit and leaves the atomic weight sensibly unaltered. Examples of these radio-active changes in atomic weight and number are given in the table on page 50.

For a Rutherford-Bohr atom the emission of an alpha particle from the nucleus gives the atom a resultant negative charge of two units, and consequently it will tend to lose two electrons. If these are valency electrons, the element will certainly possess chemical properties which should correspond with those of an element two places to the left in the periodic table. Similarly the emission of a beta particle from the nucleus gives the atom a net positive charge of one unit, and it will therefore tend to capture an extra electron, which gives the atom chemical properties corresponding with those of an element one place to the right in the periodic table.

To illustrate the interpretation of the Displacement Law on the Alternative theory, we will take a concrete example: radium, a bivalent element with atomic weight 226 and atomic number 88, changes into an inert gas, radon, with atomic weight 222, atomic number 86, and no valencies.

Radium has two d^+ valency units. These are alpha particles with one electron instead of two. To function as chemical links, the orbits of these particles must be more elliptical than the remaining units of the outer structure. To fulfil the Displacement Law,

each operative alpha particle must, on collision with the nucleus, capture an electron, and there must also be an increase in the kinetic energy of the alpha particle, sufficient to permit it to escape from the atom. The reason why only one particle escapes instead of two is that the second would have to escape from a quadruple ionized atom. The surplus energy of the alpha particle which remains may be emitted in the form of electro-magnetic radiation. In this way, an atom of radium ejects an alpha particle, and the result is a new element having an atomic weight four units lower, an atomic number two units lower, and chemically inert instead of bivalent. This element is radon, which in turn ejects an alpha particle, by a similar mechanism and with corresponding consequences. In this case, since there are no d^+ units in the atom, the operative particles are alpha units, which, on capturing two electrons from the nucleus, become d^- units. Now the Displacement Law tells us that these d^- units must remain in the atom, and consequently their surplus energy must be absorbed in whole or in part by an alpha unit, which thus acquires sufficient kinetic energy to escape.

The new atom is Radium A with two d^- valency units. This atom also ejects an alpha particle, decomposing into Radium B, with four d^- valency units.

With Radium B we meet a different type of disintegration. The emission from this atom is a beta particle. This beta particle cannot come from the nucleus since it would lower the nuclear charge instead of increasing it as required by the Displacement Law. We must, therefore, suppose that the mechanism described above is a reversible process, that instead of the operative unit capturing an electron from the nucleus, the nucleus captures an electron from the operative unit. By this means the nuclear charge is increased by one, whilst one of the d^- valency units of Radium B is converted into an inert alpha unit, thus reducing the valency to three. Now the electron captured by the nucleus was moving with high velocity, and as in the case of X-rays, its sudden stoppage must produce high frequency radiation, and this radiation will be capable of ejecting free electrons from the atom. Thus a beta particle is a free electron which has absorbed high frequency radiation or gamma rays, the source of the radiation being within the structure of the atom which emits the beta particle.

It has already been proved experimentally that at least some of the beta particles are not ejected from the nucleus but are liberated from the outer structure by gamma rays, and the characteristic beta ray spectrum is known to be solely due to extra-nuclear electrons. There is no direct physical evidence to

prove that any beta particles actually emanate from the nucleus.

In the case of Radium E, where the beta emission is not apparently accompanied by gamma rays, we must assume that for this element there is complete absorption of the gamma radiation by the beta emission.   In short, not only is there nothing in these conceptions inconsistent with experimental fact, but we can provide immediate explanations of observed phenomena for which a satisfactory interpretation cannot be found on the orthodox theory. The position is that the mechanism of radio-activity suggested by the Rutherford-Bohr theory is almost too simple. It is in perfect agreement with the Displacement Law, but is of surprisingly little assist-ance, particularly in regard to beta rays. This con-tention is endorsed by the following extracts from the 1930 edition of Rutherford's " Radiation from Radio-active Substances ":

" The investigation of radio-activity during the last twenty-five years has led to the accumulation of a wealth of data concerning the emission of energy in the form of alpha, beta and gamma rays from the radio-active nuclei, and in nearly all cases the rate of disintegration of the element has been determined. This information must have an intimate bearing on the structure of the radio-active nuclei, and it pro-

vides a variety of quantitative tests which can be applied to any hypothesis of this structure. It is, however, only within very recent times that a picture, even of the most general type, has been given which will explain satisfactorily the emission of an alpha particle, and no application of this has yet been made to the emission of the beta and gamma rays."

In the same volume Rutherford writes:

" We must conclude that in a beta ray dis-integration, the nucleus can break up with emission of an amount of energy that varies within wide limits. No satisfactory interpretation has yet been given of this curious result, so much in contrast with the high degree of definiteness and homogeneity shown by the alpha ray disintegrations."

This fundamental difference between the beta and alpha emissions is, on the Alternative theory, simply due to a different mode of ejection from the atom. We also see why beta rays are always associated with gamma rays. More important still, we can explain these spontaneous disintegrations without invoking the aid of Fate. Doubtless, however, Jeans is right when he describes radio-activity as an '' accidental '' phenomenon, because, unlike light, there is no indica-tion of purpose in its origin, or in the laws which govern it. It happens to be an inevitable consequence of atom building. Just as there are practical limits

to the height of a factory chimney, so there are natural limits to the size of an atom—due to the tendency of the orbits to increase their ellipticity as the atomic number increases.

In general, the Alternative atom in its interpretation of radio-activity is compatible with observed facts, and brings the phenomenon within the control of the Law of Causation.

Electrical conductivity is difficult if not impossible to explain satisfactorily on the orthodox theory. For example, aluminium has 3 valency electrons and sulphur has 6. There is no apparent reason why aluminium atoms should conduct electricity better than sulphur atoms, but the fact is that aluminium is over one million million times better than sulphur as a conductor of electricity. This is very remarkable. The matter is obviously of vital importance to atomic theory, but there is no answer to it. We are faced with the same difficulty in accounting for the complete absence of flame spectra of certain elements.

The Alternative-atom provides an immediate explanation. The answer is that the sulphur atom has no free electrons. It is therefore not surprising that there should be this astonishing difference in conductivity, because sulphur is not provided with a mechanism for the purpose. It is inevitably an insulator and not a conductor. Similarly silicon is a good insulator, but owing to the fact that its second

isotope has one free electron, it is not so good as sulphur.

It might be argued that the suggested atomic structures of the Alternative atoms have been built up with fore-knowledge of these properties, but a careful comparison of atomic numbers with atomic weight will show that there is something more than coincidence in the occurrence of metallic properties. In general the heavier elements tend to be strongly metallic and the lighter elements non-metallic. Why should this be? If we exclude liquids and gases, five out of a total of eight non-metals are found amongst the first twenty elements. The remaining three are high amphoteric, and display both metallic and non-metallic properties.

The five light solid elements which are non-metals are boron, carbon, silicon, phosphorus and sulphur. Of these, boron and phosphorus are border-line substances. For example, boron, at the moderate temperature of $650°$ C. is as good a conductor as aluminium. This process of elimination leaves only three solid elements to which the term non-metal can be applied without ambiguity, namely carbon, silicon and sulphur.

For the principal isotope of each of these solid elements the number of protons is exactly double the atomic number, whereas for all the other solid elements the number of protons is more than double

the atomic number, as illustrated in the following table:

ABSOLUTE NON-METALS (SOLIDS)

		Number of protons (W)	Atomic number (N)	W-2 N.
Carbon	(12)	12	6	0
Silicon	(28)	28	14	0
Sulphur	(32)	32	16	0

OTHER ELEMENTS (SOLIDS)

		Number of protons (W)	Atomic number (N)	W-2 N.
Lithium	(7)	7	3	1
Beryllium	(9)	9	4	1
Boron	(11)	11	5	1
Sodium	(23)	23	11	1
Magnesium	(25)	25	12	1
Aluminium	(27)	27	13	1
Phosphorus	(31)	31	15	1
Potassium	(39)	39	19	1
Iron	(56)	56	26	4
Copper	(63)	63	29	5
Silver	(107)	107	47	11
Gold	(197)	197	79	39
Uranium	(238)	238	92	54

Assume for the moment that, beyond a knowledge of atomic weights and numbers, we have no preconceived ideas as to atomic structure. We should certainly expect to find some fundamental reason for this apparent connection between metallic properties and the simple function (W − 2 N). But this func-

tion has no physical significance on the Rutherford-Bohr theory, because if W is greater than 2 N, we merely assume that some extra electrons are present in the nucleus. Consequently we are quite unable to give any adequate electronic interpretation to such a remarkable phenomenon, as the difference in conductivity between aluminium and sulphur.

If we invert the atomic structure of the orthodox atom and make it comply with known facts in regard to valency and other atomic properties, we find that each atom has a characteristic number of free electrons, the actual number being largely outside our control. For example, it can easily be seen that although the atoms of magnesium and aluminium have respectively two and three free electrons, we could not give beryllium and boron more than one free electron each. It is significant that beryllium and boron are fundamentally different from magnesium and aluminium in electrolytic behaviour; they do *not* form doubly and trebly charged ions as one would expect on orthodox theory, but nevertheless they are both metallic conductors.

We must now inquire how we are to interpret the known variation in conductivity as between one metal and another. As a tentative hypothesis, let us suppose that each valency unit can hold or tend to hold a free electron. Thus a monovalent atom can capture one, a bivalent atom two, and so on.

On this supposition we may regard each valency unit which has not already captured an electron, as a potential obstruction in the free path of an electron. If this were so, beryllium should be a worse conductor than lithium and boron worse than either. This is quite correct. On the other hand, magnesium and aluminium should be slightly better than sodium, because their isotopes supply more free electrons than there are valency units. For example, the 25 isotope of magnesium has 3 free electrons and only 2 valency units. Copper is unique amongst the lighter elements in having a principal isotope with more free electrons than valency units, and hence we should expect its conductivity to be very good. Electrical conductivity also varies with the structure, for example, although graphite as a conductor is about two thousand times worse than copper, it is very much better than diamond.

When we consider the conductivity of gases, we are faced with another phenomenon, the very familiarity of which has somewhat obscured the necessity for providing a satisfactory explanation, namely the remarkable conducting powers of the inert gases. *Ex hypothesi* one would expect an atom of neon constructed on the Rutherford-Bohr system to demonstrate, by abnormally low conductivity, its resistance to the addition or subtraction of electrons from its outer shell of eight. For chemical pur-

poses, we stipulate this exceptional resistance, which is simply a resistance to ionization. For electrical purposes, however, we must ignore the octet conception because we find that the inert gases part with their electrons with the greatest facility. In fact this property, when harnessed in a neon tube, provides one of the most important means of commercial illumination.

Now it is obvious that an orthodox Rutherford Bohr atom should not behave in this manner. On the other hand, we see that as Alternative atoms helium, nitrogen, neon, argon, krypton, xenon and mercury, all have free electrons, whereas carbon and oxygen have none. Further, the number of free electrons has no connection with the chemical properties. For example, nitrogen and neon have two, argon four, krypton eight, xenon fourteen and mercury twenty. Thus we should expect to find that gases ionize in a manner consistent with the above figures, and without any regard for the electronic theory of valency. On this point, I cannot do better than quote Sir J. J. Thomson, describing his observations on ionization phenomena under " positive ray " conditions.

" The atoms of the electro-negative elements, oxygen and chlorine, are remarkable for the ease with which they acquire a negative charge, and though

negative charges occur on atoms of hydrogen and
carbon, which are not usually regarded as electro-
negative, yet there are many gases, e.g. helium,
nitrogen, neon, argon, krypton, xenon and mercury,
of which I have never seen the parabolas correspond-
ing to the negative atoms, though those correspond-
ing to the positive atoms have been very strong.
Again, negatively electrified molecules, with the
exception of those of hydrogen, oxygen and carbon,
and these but sparingly, have never been detected
with the positive rays.

" The maximum number of charges carried by
a multiply charged atom does not seem to be related
to any chemical property of the atom such as its
valency, but to depend mainly on the atomic weight;
thus mercury, the most massive atom on which
observations have been made, can have as many as
8 charges, krypton 4 or 5, argon 3, neon 2, nitrogen
and oxygen 2. . . . The atoms of the inert mon-
atomic gases, neon, argon and krypton, are remark-
able for the ease with which they acquire multiple
charges."

These observations fully confirm what we have
predicted from the Alternative theory, in regard
to the general variation of ionization with atomic
weight rather than with chemical properties. The
remarkable behaviour of the inert gases in this respect

is evidence that valency has nothing to do with ionization, in the case of these particular elements. The reason why in electrolysis, ionization appears to be governed by valency, is simply that each valency unit of a metal tends to hold one free electron, and when chemical union occurs these electrons are displaced, and captured by the " electro-negative " partner which always has unoccupied valency units available for this purpose.

Thus it is not surprising that in sodium chloride, for example, the chlorine atom should capture the electron liberated by the act of union, and retain it when the partnership has dissolved. In this way it is clear that the number of electrons liberated from the metallic atom and immediately captured by the non-metallic atom, is strictly governed by valency, but it is equally clear why Thomson's positive ray experiments on non-chemical ionization should give these remarkable results so difficult to account for on the Rutherford-Bohr theory.

We also see why oxygen and chlorine so easily acquire negative charges under positive ray conditions. These elements have no free electrons and can only form positive ions if bound electrons are knocked out of their valency units.

On the other hand each valency unit of an atom of oxygen or chlorine is a trap for a stray electron. This appears to be the correct interpretation of the

supposed tendency of " electro-negative " elements
to gain electrons.

We must recognize that mass rays are really the
only direct means whereby we can actually measure
the multiple charges which atoms tend to acquire
when freely ionized.   Such direct evidence is there-
fore of profound importance.

In view of the fact that the inert gases part with
their electrons with the surprising facility noted by
Thomson, it is legitimate to inquire, irrespective of
all theories of atomic structure, whether such con-
ceptions as chemical union by exchange and inter-
change of electrons are not contrary to fact.

When in electronic chemistry we contemplate the
mode of union of such an element as sulphur, for
example, how do we account for the fact that sulphur
has no flame spectrum?   In covalent union one of
the sulphur electrons is supposed to spend about half
its time circulating around the nucleus of some other
atom.   If there were a sulphur electron with such
mobility, why is it that its existence cannot be
detected in a flame?

The chemist suggests that sulphur has an electron
capable of momentarily escaping from the field of its
proper nucleus to that of some other nucleus, whereas
experimental physics has failed to detect any readily
mobile electrons associated with atoms of sulphur.

With an inert gas such as neon, the position is

exactly reversed. The chemist asserts that the eight outer electrons of neon are so firmly bound that they cannot be captured by or shared with another atom, whilst the physicist knows that neon will part with *two* electrons without any indication of abnormal reluctance. Of course neon consists only of monatomic molecules, whereas fluorine, for example, consists of diatomic molecules, but since the fluorine atoms in F_2 are each supposed to have achieved a neon-like structure, why should they be more loath to part with electrons than neon?

It might be claimed that the free electrons, which on the Alternative theory are associated with certain atoms and not with others, are not compatible with measurements of ionization potential. For example, in tables of physical constants, the ionization potential of sulphur is given as 10·31 volts. Ostensibly it would appear that direct measurements had been made, proving that an outer electron can be removed from sulphur at this quite moderate voltage. For many elements such measurements have actually been made, but not for sulphur. The ionization is purely hypothetical, and is deduced from spectroscopic data. There does not appear to be any evidence of atoms of sulphur ever having been *observed* in a positively ionized state.

We have already rejected the orthodox electronic mechanism of chemical union for purely mechanical

E

reasons.   Clearly we are also justified in rejecting it as inconsistent with experimental fact.

If the electronic theory is wrong, by what mechanism can we replace it?   In this way we complete the circle of our argument because we cannot conceive a new mechanism without a different kind of atomic structure, and we cannot have this unless we go back to the origin of the present atom, and examine the problem of reconstruction.   We have seen that there is only one alternative to the accepted theory.   If, therefore, the first is wrong, the other must necessarily be right.

We have already discussed the pioneer work of Mosely, in determining the variation in nuclear charge by X-rays.   Since then a vast amount of X-ray data has accumulated, and this has enabled the inner electronic structure of the Rutherford-Bohr atom to be very fully worked out, although finality has not yet been reached, and a number of technical inconsistencies are found.   Is it reasonable to suggest that the electrons which are supposed to be ejected by X-rays from the innermost levels of the atomic structure do not really exist?

If we have absolute confidence in the Law of Causation, and in the logical sequence which has determined the structure of the Alternative atom, we *know* that these inner electrons are purely imaginary, and our only problem is therefore to

correlate the observed phenomena with what we believe to be the real atomic structure.

It is difficult to describe quantum phenomena in other than mathematical terms, but we can nevertheless state categorically what general conditions must be fulfilled by the quantum-structure of an atom if it is to satisfy our conceptions of physical reality. Thus we have already shown that an orbit or energy level must be such as to permit finite perturbations, however small. Further, using for descriptive purposes the language of force rather than energy, a stable position must be such that any small displacement is associated with a restoring force. Therefore, for a stable level the force of attraction must *diminish* for a small displacement towards the nucleus, and must *increase* for a small displacement away from the nucleus, thus reversing the normal variation in force. The radial range over which this reversal operates must obviously be very small in relation to the dimensions of the atom.

At the outer limit of the stable range the attraction must diminish, and at the inner limit it must increase.

It follows that an energy level is characterized by a finite range of stability, at one end of which the field of force is a maximum and at the other end a minimum. Theoretically, any position within this range will be stable, but the position of maximum

stability will be that for which the rate of change of force is a maximum, that is when the second force differential is zero.

There is no escape from this force-picture of an energy-level unless we repudiate force conceptions entirely. Consequently with a *negative* nucleus, an energy level is, for an electron, a range of maximum *instability*. Further, the outer limit of the energy level is a position of maximum *repulsion*.

It presents a barrier which the electron can only pass if its energy is sufficient.

If, therefore, we bombard negative nuclei with electrons, the energy levels associated with the nucleus define the positions at which electrons tend to be stopped. The level to which an electron will penetrate will depend on its velocity. The outer limit of each level may be regarded as a barrier through which the electron may pass only at the expense of a certain loss of energy, which must be emitted in the form of radiation. This process of absorption of energy from the electron will only cease when the electron is finally stopped at the innermost level to which it has been able to penetrate.

Thus we should expect high frequency radiation to be excited when we bombard with high speed electrons, any element whose atoms are constructed on the Alternative theory. This is exactly how primary X-rays are generated. Further, the X-rays

so produced indicate that the frequency is governed by the existence of energy levels within the atom because the characteristic X-ray spectra of the element bombarded are always present with the primary rays.

If such radiation is allowed to impinge on any other element, a free electron which absorbs a quantum of energy from the radiation will acquire the same velocity as the primary electron, and will in turn, on penetrating the energy levels of an atom, emit similar radiation. We thus have a logical mechanism for the generation of both primary and secondary X-rays.

It is obvious from the foregoing that we must expect to find some inconsistency in the corresponding X-ray mechanism of an orthodox atom. The characteristic X-rays of an element are supposed to be due, not to penetration of an atom by an electron, but to the ejection of an electron from the atom. This is, of course, perfectly consistent with energy level measurements as indicated by the observed lines in the X-ray spectra. Characteristic X-rays emanating from the element on the target are likewise supposed to be due to electrons which have been ejected by the primary rays at their source. What, then, is the origin of the primary rays themselves? They cannot possibly be generated by electrons which have been ejected from the atom by radiation, because we have no radiation available. All we have are high

speed electrons.   Here, then, is the difficulty we anticipated.   We know that the electrons are stopped when they hit the target, and the result is high frequency radiation.   To produce this radiation we must suppose some mechanism, *other than the radiation itself*, capable of ejecting electrons from the inner levels of the atom.   In short, we have a simple theory to explain the secondary effects, but we cannot adequately explain the real origin of the phenomenon.

In terms of accepted theory, the primary X-radiation is, rather vaguely, supposed to be generated by the stoppage of the electrons at the target, but, as we see, it is essential that the mechanism of the " stop " should be investigated in some detail.   There are very few text-books on X-ray work, and, unfortunately, the authors accept the phenomenon without clearly explaining its origin.   The difficulty is that in order to account for the generation of primary X-rays, at least some of the electrons which bombard the target must be stopped instantaneously and at once deprived of the whole of their energy.   We have shown how this condition is quite simply fulfilled by the Alternative atom.   If there is an equally satisfactory explanation on the Rutherford theory, it has not yet been published.   In chemistry, radioactivity, spectroscopy and conductivity we have found similar difficulties, in each case at the very origin of

the phenomena: we cannot explain what causes atoms to unite, to disintegrate, to emit or not to emit light, to conduct or not to conduct electricity. Is it surprising that we cannot, on the orthodox theory, explain the ultimate causes of X-ray phenomena?

Is it surprising that we begin to doubt, like Jeans and Eddington, whether it is any longer worth while expecting atoms and electrons to obey the Law of Causation, any more than we should be able to follow the line of thought of a logician if we were to hold his book upside down and still try to read it from left to right. We might possibly discern some kind of order in the sequence of the hieroglyphic, but no grammar, syntax, logic or meaning. This is inevitably a legitimate analogy with one of the two possible systems of atomic structure which we are here considering.

In passing, we may note that the characteristic K spectrum of an element requires that all the electrons responsible for the lines are able to penetrate as far as the K level, where they are stopped.

Some get through to the K level without loss of energy, whilst others arrive having lost part of their energy at the outer barriers. This is a curious result, and we must conclude that an energy level barrier cannot be a homogeneous structure, but that there are gaps in it.

It appears that this is also a consequence of the

wave mechanics theory, and is consistent with experimental observations.

We have seen that the Alternative atom has an outer structure which is built up of a limited number of units, namely one-mass units, two-mass units, three-mass units and four-mass units. What evidence is there that these units actually exist? The answer is that one-mass units have been ejected from the atoms of many elements by Rutherford. Four-mass units are spontaneously ejected from atoms in radio-active disintegration; three-mass units are required as valency units for a very large majority of the elements, and these can apparently be freely knocked out of atoms under suitable conditions. For example, Sir J. J. Thomson observes: "There is a strong line due to a substance with atomic weight 3. This is typical of what is observed when substances such as the metals platinum, palladium, aluminium, copper, zinc, iron, nickel, silver, gold, lead, graphite, and a large number of salts are first bombarded with cathode rays."* He was very puzzled as to the origin of the " 3 " line, and although he suggests that it may be a molecule of H_3, he cautiously states: "I do not feel certain that in some cases the ' 3 ' line may not arise from some other cause." He does not explain what other possible causes there might be, but it is a remarkable

* "Electrical Conductivity of Gases," Sir J. J. Thomson.

fact that every element for which Thomson found the " 3 " line, has 3-mass units in the new structure which we must assign to it, as a result of our inversion of the orthodox atom.

Two-mass units have recently been discovered in the form of " heavy " hydrogen. The nucleus of this atom must, on any theory, consist of two protons and one electron. The nucleus of " diplogen " is probably a " b " unit, and the origin of heavy hydrogen may perhaps be traced to elements which have accidentally lost their " b " units, just as they may lose their " c " units, as demonstrated in J. J. Thomson's experiments cited above.

The ejection of single protons from light elements when bombarded with alpha particles brings us to an interesting point. We have seen that it is necessary to assume that any single protons are placed close to the nucleus. Consequently, when an element is bombarded, the alpha particle projectiles will tend to be directly attracted by the atomic nuclei, and if they pass near enough will be captured and will revolve close to the nucleus in orbit. Thus single protons which happen to be in this region are likely to get knocked out of the atom. This is a very simple explanation of the observed fact that the ejection of a proton is usually accompanied by the capture of the alpha particle, a fact which is otherwise rather unexpected. Obviously we cannot change N^{14} into

O^{17} by this means. What we get is N^{17}, because the charge on the nucleus is unaltered, and so are the chemical properties. Contrary, therefore, to present belief, this process is not necessarily a transmutation of one element into another.

The most direct physical method of determining whether the charge on the nucleus of an atom is positive or negative, is to bombard a given element first with positively charged particles and then with negatively charged particles.

As a reference basis, let us conceive a neutral substance whose atoms have neither a positive nor a negative nuclear charge, and let us suppose that positive particles projected through such a medium have a finite range. It follows that with positive nuclei, positive particles will have a less range and negative particles a greater range; conversely with negative nuclei, positive particles will have a greater range and negative particles a less range.

Now what are the observed facts?

These can be summarized by two quotations from " Radiation from Radio-active Substances," Rutherford, Chadwick & Ellis.

1. *Absorption of alpha particles.*

" The result can be brought into accord with the theory if it be supposed that the number of collisions are twice as numerous as those calculated

by classical mechanics on Bohr's theory." (Page 118.)

2. *Absorption of beta particles.*

" It is seen that the calculated ranges are only 60 to 65 per cent. of the observed values." (Page 143.)

In the first case, the range is approximately double what would be expected from positive nuclei, and in the second case it is roughly one-half the expected range.

Now if the nuclei are negatively instead of positively charged, this remarkable discrepancy between experimental fact and the expectations of the Rutherford-Bohr theory is inevitable.

Further, on both theories hydrogen atoms have a positive nucleus. Consequently the absorption behaviour of hydrogen, viewed from the standpoint of orthodox theory, should appear anomalous, as compared with the known behaviour of other elements. This is a matter of experimental fact which can be adequately summarized by a quotation from Andrade:

" Hydrogen behaves anomalously with reference to absorption in general—it may be said that no valid explanation has so far been offered." (Andrade, " Structure of the Atom," pp. 42-44.)

We must now review the sequence of this investigation. First, we point out that the Rutherford-Bohr atom is of doubtful validity, since it appears to involve a breach of the Law of Causation. We then examine its origin for possible alternatives. We find that the quantum conditions which permit the orthodox atom, simultaneously permit an alternative. We consider in parallel the atomic structure of the first six elements on both systems, and note that the continuous variation in nuclear charge and the discontinuous variation in chemical and physical properties are in general more consistent with a negative than a positive nucleus.

We then deal with the mechanisms whereby electrical systems such as nuclear atoms may unite, pointing out the necessity for providing simultaneously both an urge and a means for union. We see that the orthodox atom fails to satisfy this fundamental requirement, whereas the alternative construction compels the use of units consisting of groups of protons and electrons, each unit being capable of providing an electro-magnetic link. Methods of constructing chemically inert elements are then considered and contrasted, and we note that the accepted interpretation of chemical inertia depends on the supposed " stability " of certain numbers, whereas on the Alternative theory, chemical inertia is secured, and more logically, by eliminating electro-magnetic

resultants. The atomic weights of the inert gases are seen to conform with the new hypothesis.

The alternative constructions of hydrogen, lithium, beryllium, boron, carbon and nitrogen are worked out, and we see that only one construction is possible. We also deduce that with certain elements there must be free electrons, in order to make the atom electrically neutral. These free electrons must be easily excited, because they are repelled by the nucleus of the atom to which they are normally attached.

The two electronic types of chemical union, namely covalency and electro-valency, are shown to be compatible with an electro-magnetic linkage, with or without the displacement of free electrons. In this way a positive mechanism for chemical union is established which also satisfies ionization phenomena.

It appears that the superstructure of the science of optical spectroscopy is substantially unaltered by the Alternative atom. We can account, however, for the existence or non-existence of the flame spectrum of an element.

An investigation is made of the mechanism by which the Alternative atom provides for spontaneous disintegration controlled by causation, fully consistent with Soddy's Displacement Law of Radio-active Change, and consistent with Rutherford's discovery

that " The Quantized Orbit is essential to provide for the well-established fact that the alpha particles are liberated from a radio-active nucleus at a definite velocity characteristic of the element."*

The phenomenon of electrical conductivity is directly accounted for by the presence of free electrons, and this explains why the conductivity of one element may be as much as ten million times the conductivity of another. Differences of this order are obviously extremely difficult to reconcile with orthodox atomic structure. Similarly the origin of metallic and non-metallic properties is accounted for, and we see that the tendency for metallic properties to increase with atomic number is directly due to the more rapid increase in atomic weight, with a consequent increase in the number of free electrons per atom.

The inert gases are also required on the Alternative system to have free electrons. It is therefore concluded that atomic ionization phenomena must have no relation to the valency properties of the element, and we find that direct experiments by Sir J. J. Thomson provide remarkable confirmation of this, and equally remarkable denial of the supposed electron stability of the outer shells of inert gas atoms. This evidence is correlated with the absence of physi-

* " Radiation from Radio-active Substances," Rutherford, Chadwick & Ellis.

cal electronic phenomena in non-inert elements such as sulphur, and we conclude that the electronic theory of atomic union appears to be without physical foundation.

An analysis of the conditions under which atoms will emit high frequency radiation, when they are bombarded by electrons, compels us to define in some detail the structure of an energy level. This interpretation of characteristic X-ray spectra involves the interesting deduction that there are gaps in energy levels through which an electron may pass unobstructed. We show that the mechanism required by the structure of the Alternative atom for the generation of primary and secondary X-radiation is consistent with the ascertained origin of the phenomena, whereas for the orthodox atom the precise origin is unknown.

The remarkable experimental results of the absorption measurements for positive and negative particles are seen to be consistent with a negative rather than a positive nuclear charge.

Finally we can account for the unexpected ejection of particles of mass 3 from large numbers of elements when bombarded by electrons, we can account for the ejection of single protons when bombarded by alpha particles, and for the ejection of 4-mass units, gamma rays and electrons when the atom is radio-active. In every case both the mechan-

ism of ejection and the behaviour of the ejected particles indicate that they have come from the outer structure and not from the nucleus.

In spite of the general coherence of the Alternative theory, it is legitimate to ask : " How can it be true, in view of extensive quantitative confirmation of the Rutherford theory? " Let us therefore review this quantitative work to see whether we can find anything which will disprove the new theory. First, the equations governing the angles of scattering of alpha particles by atomic nuclei are independent of the sign of the nuclear charge. This can easily be seen by inspection of the formulae.* If it were not so, there would be no chance of an Alternative theory! Secondly, as we have already pointed out, hydrogen is identical on both systems, so that all quantitative work on this element, including Bohr's classical calculation of the Balmer series, is common to both theories. Investigation of the absorption of alpha and beta particles indicates very large errors in the quantitative estimates derived from the Rutherford-Bohr theory, to which we have already drawn attention. In the field of radio-activity there is so far very little mathematical investigation of other than empirical value. Even the important Geiger-Nuttall formula has not yet received a convincing mathematical interpretation. In spectro-

* Cf. Andrade, " Structure of the Atom," p. 22.

scopy it is obvious that no distinction can at present be made between two hypothetical atoms, both of which picture an electron moving in the field of a positively charged core. Thus the general theory of spectrum analysis is equally applicable to both types of atom, and it is no use attempting to put forward new quantitative interpretations of spectroscopy, because the existing mathematical machinery is necessarily common to both systems. For different reasons, the same may be said of X-ray spectroscopy. In this case, the strength and distribution of the energy levels around a given nucleus are dependent on the charge of the nucleus but not on the sign of the charge. Mathematical investigation of the magnetic properties of the atom has gone far ahead of qualitative explanation of magnetism itself. This work will no doubt be useful eventually, but it has so far failed to explain why iron should be so highly magnetic whilst other atoms, manganese, for example, should be non-magnetic. Since, after all, this is the paramount fact in regard to magnetism, a satisfactory explanation, either qualitative or quantitative, is essential. Similarly, in regard to electrical conductivity, a fairly satisfactory mathematical theory has been developed, but this begins by assuming free electrons to be present in the conductor. It does not attempt to explain their origin. Since the Alternative system accounts for the presence of these free

electrons in metals, but not in non-metals, it will be perfectly legitimate for us to accept the theory of metallic conductivity which has already been developed.

In short, although the Alternative atom as defined in the foregoing pages may seem at first sight to be lacking in mathematical background, as compared with the Rutherford atom, the reason is that all the important quantitative work appears to be equally applicable to both theories of atomic structure, just as an object and its reflection share the same mirror. On the other hand the Rutherford atom is seriously lacking in qualitative background, which, after all, is no less important. This is equivalent to stating that by comparison with an object, a reflection is lacking in *reality*; nevertheless a distant observer who only sees the reflection might easily assume that what he sees is real.

If, however, he sees both the object and the image, it should not be difficult for him to decide which is which.

So far we have confined this investigation to a comparison of the two atoms in their interpretation of the mechanism by which the chief phenomena of science are produced. Even though one atom appears to have far more appearance of reality than the other when viewed from this standpoint, let us make a rather more detailed investigation to see what further

evidence there may be which may help us to distinguish clearly between object and image.

The most exciting way of doing this is to make predictions from the new theory and see whether they are fulfilled, and whether the accepted theory could have made the same predictions. Now it is always much more satisfactory to know the answers before making predictions, and experimental science has so far outstripped theoretical science that the answers to most theoretical predictions are already known. Thus to test the new theory, it is necessary to try to free one's mind of all knowledge of ascertained fact, otherwise it will be quite impossible to form sound estimates of the value of predictions fulfilled.

To both the chemist and the physicist the most outstanding fact in regard to the elements is that some are " metals " while others are " non-metals." There are, of course, profound differences between the two types of element in most of their chemical and physical properties. Let us try to imagine that we know nothing of this.

With the Rutherford model one pictures ninety-two elements, all constructed on the same pattern with a positive nucleus surrounded by electrons. It is extremely disconcerting to find that there is no suggestion of any distinction between one atom and another which might, for example, enable us to

divide them into two main groups with very widely differing properties.

The Alternative atom, on the other hand, by inverting the accepted structure, presents a curiously different picture. Without knowing any facts in regard to each element, other than its atomic weight, atomic number, and chemical valency, we can at least predict that amongst the light elements there may be some which have no free electrons, and we should look for these amongst the elements whose atomic weight is double the atomic number.

It would also be obvious that amongst the heavier elements there would be, for arithmetical reasons, a rapid increase in the number of elements with free electrons as the atomic number increases.

Naturally one would expect to find some marked differences in behaviour between elements with free electrons and elements with none. One would predict differences mainly in electronic phenomena, as, for example, electrical conductivity, photo-electric and themionic effects, ionization, salt formation and so on, leading to the recognition of two possible types of atom, say A and B, which, although not fundamentally different in structure, differ in so far as they do or do not carry with them parasitic electrons.

Since atoms of type A must necessarily have more free electrons per atom as the atomic number increases, one might generalize further and predict

that the properties which are *characteristic* of type A will tend to become more accentuated as the atomic number increases.

Further, it is evident that an atom which has a cloud of negative particles in its outer atmosphere, repelled by the negative charge on its nucleus but attracted by the positive charges on its core, will find its mechanism for chemical linkage somewhat hampered. Thus one would predict a general increase in chemical inertia as atomic number increases.

Per contra, the most active elements should be those which have more valency units than free electrons.

Thus we can not only predict the existence of " metallic " and " non-metallic " atoms, but we can predict the increase in metallic properties as atomic weight rises, and also explain the otherwise rather remarkable fact that the " metallic " atoms are chemically so inert but electronically so active.

Familiarity with these major facts of chemistry has tended to obscure the fact that they are, from the point of view of the Rutherford picture of atomic structure, most extraordinary and inexplicable phenomena. Thus it is impossible to assess properly the significance of this in relation to our " object and image " problem, unless these major variations in the properties of the ninety-two elements are recog-

nized as being hitherto left without adequate or even any explanation.

Space does not permit of each of these ninety-two elements being considered in detail, but we can at least consider the first few elements. This should suffice to show how the new theory responds to more detailed investigation.

Since the Alternative atom demands electro-magnetic linkages, it is obvious that a hydrogen atom which has lost an electron must dissociate, because it is the rotation of the electron round the nucleus which sets up the electro-magnetic field by means of which a hydrogen atom, on the new theory, is able to unite with other atoms equipped with the same type of linkage-mechanism.

There is, however, a very important distinction between the electro-magnetic link of hydrogen and that of lithium. The single electron of the hydrogen atom is essential to chemical union, because if it is removed union is no longer possible. The single free electron of lithium must, on the other hand, be removed in order to make union possible, because it naturally tends to obstruct the electro-magnetic field of the single valency unit of the lithium atom, owing to its electrostatic attraction towards the valency unit.

Thus on the new theory one predicts that hydro-gen *in a chemical compound* can never, whilst lithium must always, be positively ionized. For

example, solid hydrogen chloride is shown by X-ray crystal analysis to be non-ionized, but when dissolved in water some of the hydrogen atoms lose their electrons and dissociate, giving the " hydrogen ion concentration " which is characteristic of an acid. On the other hand X-ray analysis shows that solid sodium chloride is always ionized.

This anomaly in the behaviour of hydrogen as contrasted with *other monovalent elements* is, as we see, predicted by the new theory. Could it have been predicted equally well by the accepted theory? The answer is in the negative. There is no apparent reason why, if solid sodium chloride is an ionized compound, solid hydrogen chloride should be a non-ionized, covalent compound which dissociates as soon as it ionizes.

Further, an electro-magnetic theory of valency necessarily requires that hydrogen may be both monovalent and bivalent, because it can obviously exert a magnetic attraction on both sides of the plane of its orbit. In this respect it is unique, because it is impossible for the alkali metals to be other than monovalent. Now several instances are known where hydrogen must be regarded as bivalent, so that this is another prediction fulfilled.

Lithium has one free electron associated with its isotope of mass 7, whereas the isotope of mass 6 has none. Consequently one would expect certain

chemical and physical differences between the two isotopes, such that in the purifying of lithium, the light isotope may be lost in whole or in part. The resultant atomic weight would then be approximately 7·0 instead of 6·94. It is a remarkable fact that as recently as 1921 the accepted international atomic weight of lithium was 7·03. This figure is referred to by Mellor as " the mean of all the most accurate determinations."

For the next element, beryllium, the most striking fact indicated by the new theory is that it only has one free electron instead of two. This should provide an interesting test, because we may at once predict that beryllium cannot lose two electrons to form a bivalent positive ion, but that it can only lose one, so that it has as it were one electro-valent link and one covalent link.

Now curiously enough this appears to be an accurate description of the two valencies of this element. Further, after positive ray tests, G. P. Thomson reported:-" No indication was found which would suggest that the atom of beryllium can lose two electrons under the conditions of the experiment." (*Nature*, 107, 395, 1921.) Again, beryllium cannot be deposited by electrolysis of the pure fused salt, as, for example, from beryllium chloride. If, however, sodium chloride is mixed with it, beryllium is promptly deposited at the cathode under circum-

stances which indicate that a positively charged sodium ion replaces the single covalent chlorine atom, thus producing a molecule which migrates to the cathode depositing a beryllium atom and two positive charges, leaving an uncharged molecule of sodium chloride behind in the electrolyte. This curious feature in the behaviour of beryllium in an electrolyte is obviously not easy to predict from the Rutherford theory.

Comparing the first three elements of the first and second short periods, it is known that whereas sodium, magnesium and aluminium give mono-valent, bivalent and tervalent positive ions, lithium, beryllium and boron all behave as though they had only one electron to lose, and with the exception of lithium are really non-conductors in an electrolyte.

Boron is supposed to be quadrivalent in certain compounds, and for this excellent reason it has presented a very difficult problem to those who attempt to explain its behaviour in terms of the three valency electrons which are allocated to it by the accepted theory. Why is it that the extra valency is only exercised when its partner is hydrogen and not with a halogen such as chlorine? The valency of every other element towards a halogen is never less than, and more frequently greater than, its valency, if any, for hydrogen.

The facts are simple and interesting. Boron

might have been expected to combine with three atoms of hydrogen, just as carbon combines with four. It does not. Instead, it appears that two atoms of boron and six atoms of hydrogen combine in one single molecule. This would be consistent with quadrivalent boron, but if boron is quadrivalent, one might have expected to find one atom of boron combining with *four* atoms of hydrogen. However, there is no dispute about the maximum valency of hydrogen: it is two. It appears that bivalency is usually accompanied by the capture of an extra electron by the hydrogen atom.

Consequently there will be one atom of bivalent hydrogen for each atom of tervalent boron. In this way the boron hydrides can be directly accounted for, and it is interesting to note that they are really ionized hydrides. They differ, therefore, from the hydrocarbons, which are invariably non-ionized, and this accords well with their great reactivity as contrasted with the inertness of the saturated hydrocarbons.

Many suggestions have been put forward to explain the unorthodox behaviour of boron in terms of the orthodox theory, the most recent being an ingenious suggestion that an electron may sometimes be shared by three nuclei! If this were so, one would then have to explain why electrons only do this when one of the nuclei belongs to a boron atom.

It is evident, however, that there is nothing really surprising about the boron hydrides. The surprising thing would be if hydrogen were not sometimes bivalent. It is curious that beryllium is the only element in the first short period which does not appear to form a hydride. By analogy with boron it is possible to explain why a molecule comprising one atom of beryllium and two of hydrogen has not been observed, but one would expect to form, under suitable conditions, a molecule containing two atoms of beryllium and four of hydrogen. This may well be the missing hydride.

The new theory provides a basis for a significant comparison between carbon with four valency units and no free electrons, oxygen with four valency units and no free electrons, and the intervening element nitrogen with five valency units and two free electrons.

We can predict that nitrogen should be semi-metallic in properties. To what extent is this prediction fulfilled? There is no doubt about the non-metallic chemical character of carbon. It is the basis of organic chemistry. A direct comparison between the two gases is, however, very illuminating:

NITROGEN AND OXYGEN

Nitrogen[14]	Oxygen[16]
Rutherford-Bohr atom: 5 valency electrons. Alternative atom: 2 " free " electrons.	Rutherford-Bohr atom: 6 valency electrons. Alternative atom: no free electrons.
Solid nitrogen readily forms into opaque white crystals, but can with difficulty be made to form transparent crystals.	Solid oxygen solidifies into a translucent jelly and hardens into a vitreous substance with minute crystals embedded in it.
Solid nitrogen is highly luminescent, particularly when bombarded with cathode rays.	Solid oxygen has no such property.
In chemical compounds atoms of nitrogen are much more frequently ionized than atoms of carbon and oxygen. More important is the fact that a nitrogen atom in an ionized compound usually forms part of a *positive* radicle, e.g. NH_4, which is equivalent to an alkali metal.	Oxygen favours co-valent non-ionized linkages.
Note that the " lone pair " of nitrogen corresponds to the two free electrons of the Alternative atom of nitrogen. This may explain why the best known and most characteristic of the co-ordination compounds are amines.	Oxygen is an accepter rather than a donor of " lone pairs."

Nitrogen usually confers basigenic properties on organic compounds, i.e., they then form salts with acids.	,
The semi-metallic character of nitrogen explains its chemical " inertia," a fact which has not and apparently cannot be accounted for on the accepted theory. This also explains why nitrogen is reluctant to combine with metals.	
Nitrogen *alloys* with metals. This is of significance in view of the nature of alloys (see p. 95).	The effect of oxygen is of course entirely different.
Nitrogen has a *flame spectrum*. The only other non-metal amongst the light elements with a flame spectrum is boron, which has one free electron on the Alternative system, and which is as good an electrical conductor as aluminium at 700° C.	Oxygen has no flame spectrum.
In a discharge tube, the behaviour of nitrogen resembles that of a metallic vapour.	A very small proportion of nitrogen will obliterate the line spectrum of oxygen.
Although its ionization potential is higher, nitrogen is a far better conductor of electricity in the gaseous state.	Why should oxygen be so difficult to ionize when its ionization potential is lower than nitrogen?

It is surely significant that the new theory can predict this remarkable contrast between elements

which on the accepted theory simply have five and six outer electrons respectively.

In a similar manner the chemical characteristics of other elements may be predicted and interpreted.

In considering the chemistry of the heavier elements, most of which are metals, we are brought to that nebulous region of modern science, the border-line between chemistry and metallurgy.

Since in metallurgy there is clear evidence of the formation of molecular compounds comprising two or more different metallic atoms, and since, however, all the constituent atoms are usually positive ions, with their outer electrons occupying in common the intervening spaces, it is clear that the accepted electronic theory of valency has broken down. Nevertheless a metallic atom on a crystal lattice is known to be surrounded by other atoms, the number of which is closely connected with the valency properties of the central atom. For example there is the Bradley-Hume-Rothery $8 - N$ rule, according to which if N is the number of the column or vertical group in which certain metallic elements occur in the periodic table, the number of nearest neighbours is $8 - N$. Such a rule could obviously have no general application unless *characteristic* valency properties are still retained by atoms even when their valency electrons are partially or wholly dispersed into a common electron atmosphere. This is such impor-

tant evidence in support of the contention of the new theory that valency links are inherent in the structure of the atom, and independent of the outer electrons, that it is worth while considering it more carefully. Again, the facts are both simple and interesting, and have been summarized by W. L. Bragg in a recent paper on "The Structure of Alloys,"* some quotations from which we will take the liberty of stringing together:

"The chemistry of the compounds formed when metals are alloyed together is of great interest, because its laws are of a different type to those governing inorganic and organic compounds. . . . Metals and alloys are formed by the association of electro-positive atoms, or atoms which in typical salts exist as positive ions. A metal is composed of positive ions together with a system of free electrons which is common to the whole structure. . . . The phases which appear in an alloy system are often called intermetallic compounds, and the atomic proportion of the constituents approximates to a simple integral ratio as in chemical compounds of organic or inorganic types."

It is an established fact that in metallurgy a mechanism for valency remains, even when the electrons which should provide the normal chemical

* "Transactions of Royal Institution, 1933."

valencies are transferred to a common inter-space between ions which are all tending to *repel* each other electrostatically.

It is difficult to see how a proper appreciation of the significance of these facts can result in anything but conviction that the Rutherford model of the atom and its associated mechanism for valency is incompatible with the facts of metallurgy.

If it is, on the other hand, conceded that the Alternative theory provides a consistent explanation of these features of metallic structure, as described in the above quotations from Bragg, we shall be able to proceed to another interesting and very important test of the theory, namely the interpretation of magnetism.

The new atom has a simple and direct mechanism for producing magnetic phenomena, because each valency link is, by definition, a local magnetic resultant. In fact one can picture an Alternative atom as consisting of a central spherical core from which project a number of small magnets, each magnet representing a valency. Thus all the Alternative atoms have magnetic resultants except the inert gases, all of which, it is interesting to note, are found experimentally to have nearly zero magnetic susceptibilities.

It is clear that the magnetic susceptibility of an atom can be varied by adjusting the relative positions of its magnetic links. For example, if they are

equally spaced round the core, the atom will have no magnetic moment, just as a sphere with magnets projecting radially in all directions would set itself indifferently in any position.

On the other hand the magnetic links may obviously be arranged so as to give the atom a resultant magnetic moment so that the atom as a whole acts as a single magnet.

Now this magnetic mechanism can be promptly tested because by chemical combination it should be possible to build up magnetic or non-magnetic molecules at will.

If a non-magnetic atom with equi-spaced links unites at each link with a magnetic atom, the result must be a non-magnetic molecule, because the linkages are such that the magnetic atoms are arranged around the non-magnetic core at equal intervals, and their magnetic axes are all directed radially towards the nucleus of the central atom.

For example, manganese is non-magnetic and has seven valency links which must therefore be equi-spaced round the core of the atom. If, therefore, we attach one atom of iron to each link, the resultant molecule must also be non-magnetic.

Consequently, since the atomic weights of manganese and iron are almost equal, we should expect to find that when the percentage of manganese is about 1 in 8 or 12½ per cent., the steel will be non-magnetic.

This is exactly the percentage of manganese which Sir Robert Hadfield discovered in about 1883 to be sufficient to make iron practically a non-magnetic material—a discovery, needless to say, of very great practical and scientific importance, but one which has not so far received a satisfactory explanation. It may be added that a small percentage of carbon is necessary in order to secure the best results, the carbon appearing to have a catalytic effect in facilitating the formation of the Mn Fe$_7$ molecule.

The explanation of ferro-magnetism afforded by the new theory is that the iron atom, instead of having its valency links radiating equally in all directions like manganese, has three at one " pole " and three at the other.

On the foregoing basis, many curious variations in the magnetic properties of alloys can be successfully interpreted, and a particularly interesting phenomenon is the magnetic susceptibility of the Heusler alloys, which contain only non-magnetic elements, but which may develop a high degree of " ferro-magnetism."

To account for this on the Alternative theory, we assume the formation of molecules of $MnAlCu_2$, linked up as indicated below so as to leave free electro-magnetic resultants at each end of the molecule.

south pole of magnet ←——Al⟨◇⟩ Mn——·Cu———Cu——→ north pole of magnet
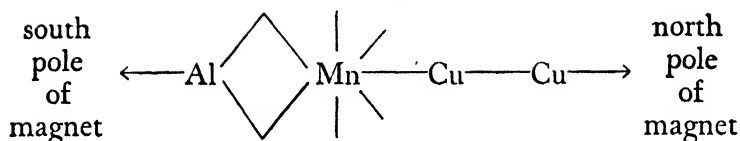
Remarkable confirmation of this explanation has been obtained by Valentiner and Becker, the results of whose *experiments* are summarized below:

"It is shown that the magnetic properties of the Heusler alloys depend on the presence of the crystal $MnAlCu_2$. Magnetic alloys of manganese, aluminium and copper, always contain the crystal in greater or lesser amounts."[*]

Thus it is an established fact that this molecule exists and is always present when magnetic properties are developed in these alloys.

Andrade, writing on magnetism with reference to atomic structure, says:

"Investigation of the magnetic properties of bodies cannot be said to have given so far any very precise information as to the structure of the atom, but, at the same time, magnetism is a physical property of such fundamental significance that it can scarcely be left out of any discussion of the subject. At present the subject seems to be awaiting some radically new theory."[†]

[*] *Zeitschrift F. Physik*, June, 1933. Summary in *Science Abstracts*, 4266/1933.

[†] Andrade, "Structure of the Atom," p. 582.

Since the accepted theory of atomic structure cannot even give qualitative explanations of the reason why iron is magnetic and manganese non-magnetic, or nearly so, Andrade is undoubtedly right in his deduction that the subject needs a radically new theory. The brief outline given above should serve to indicate the assistance which such a new theory may give in elucidating some of the problems of this important subject.

We must now review very briefly the evidence for and against the Alternative theory. It is not easy to disprove it, because it obviously interprets many atomic phenomena at least as well as the existing theory; it is difficult to show that such an inverted structure is contrary to fact. This in itself, having regard to the profound differences in structure between the two atoms, is sufficiently remarkable. The Rutherford atom is accepted by the scientific world because at the time of its birth there was no suggestion that abnormal forces due to quantum laws might come into play and make possible an unforeseen rigidity. It inspired, as a model, swift and increasing confidence, because, in spectroscopy in particular, it gave quantitative results of extraordinary accuracy. But as we have indicated these results are equally applicable to the Alternative atom.

The evidence *against* the Rutherford atom is that

whilst it shares these quantitative results common to both, it fails to give satisfactory explanations of the *origins* of natural phenomena; it fails to explain what causes atoms to unite, to emit or not emit light, to conduct or not conduct electricity, to emit X-rays, to disintegrate, to be metallic or non-metallic, magnetic or non-magnetic. In short, it fails to explain anything of a fundamental nature, which is not surprising if it is only an inverted image of reality. On the other hand can it be denied that the Alternative atom not only explains these fundamentals, but provides causes where they are missing, and predicts, as we have seen, many hitherto inexplicable diversities in the chemical and physical behaviour of individual elements.

The evidence in favour of the Alternative atom is not, however, confined to these major causes and origins, and any attempt to decide the issue between the two theories must pay proper regard to details, and it will therefore be of assistance to summarize briefly some of the questions to which the Alternative theory provides answers. For example, it explains why the elements are divided into two main groups, metals and non-metals; why the metals are chemically more inert than the non-metals; why metallic properties tend to become in general more pronounced as atomic number increases; why metallic atoms when stripped of outer electrons still retain

characteristic valencies in alloys; why the magnetic properties of alloys are governed by the chemical valencies of the constituent atoms even when the valency electrons have been removed; why alpha particles are ejected from radio-active atoms with characteristic velocities; why beta particles are usually accompanied by gamma rays; why " 3-mass " units are obtained from a large number of elements under electron bombardment; why sulphur is chemically active and optically inactive; why neon is chemically inactive and optically active; why single protons may be ejected from some elements and not from others; why the absorption of alpha particles is greater and of beta particles less than anticipated; why the absorption characteristics of hydrogen are anomalous; why hydrogen is sometimes bivalent; why hydrogen is non-ionized whilst in chemical union, and dissociates on ionization; why beryllium does not give bivalent ions in an electrolyte whilst magnesium does; why beryllium does not appear to form a hydride, whilst all-the other elements in Period I do; why boron, although a non-metal, is as good a conductor of electricity as aluminium at quite moderate temperatures; why boron appears to be quadrivalent in its hydrides and tervalent in other compounds; why nitrogen has many semi-metallic properties whilst the adjacent elements, carbon and oxygen, are both non-metallic.   Is it possible that the

ability of the new theory to answer all these questions simultaneously is merely accidental?

If the Alternative atom had been accepted in 1911, fitting the facts so well and so consistently, would it not have been absurd in 1934 to put forward a model which, for example, made no distinction between metal and non-metal?

Nevertheless absolute conviction that the Alternative model represents the real atom, and the Rutherford model its inverted reflection, is perhaps only possible for those who insist consciously or subconsciously on the inevitability of cause and effect.

Its acceptance should lead to a clearer understanding of some of the problems that remain perplexing, the greatest being the problem of Life, for the solution of which the biologist must wait until the physical scientist can give an adequate account of atomic mechanism. "The intrinsic properties of living matter are as mysterious and as fundamental as the intrinsic properties of the molecule of a radioactive substance: when the physicist can tell us why one particular atom explodes, and why another goes on existing, I venture to think that we can begin to consider the possibility of defining the fundamental properties of living protoplasm in physical terms."*

* Presidential address of Dr. J. Gray, F.R.S. Section D. British Association, 1933.

TABLE OF ELEMENTS

Atomic Number	Element	Atomic Weights	Atomic Weights of Isotopes	Valencies† −	Valencies† +	"Alternative" Structures (Units in brackets are inert)	Free Electrons
1	Hydrogen	1·008	1·0077, 2·0135	1	1*		
2	Helium	3·99	4			4P = 4	2
3	Lithium	6·94	7, 6		1*	(a)+c⁺ = 7	1
4	Beryllium	9·1	9		. 2*	(a)+c⁺+b = 9	1
5	Boron	10·9	11, 10	3	. . 3*	(2p)+c⁺+2c⁻ = 11	1
6	Carbon	12·0	12, 13	4	. . . 4*	2c⁺+2c⁻ = 12	0
7	Nitrogen	14·01	14, 15	3*	1 2 3 4 5	(p)+3c⁺+2b = 14	2
8	Oxygen	16·0	16, 18, 17	2*		(a)+2c⁺+2c⁻ = 16	0
9	Fluorine	19·0	19	1*		(2p)+c⁻+7b = 19	1
10	Neon	20·2	20, 22			(4a+4p) = 20	2
11	Sodium	23·0	23		1*	(5a+p)+b = 23	1
12	Magnesium	24·32	24, 25, 26		. 2*	(4a+2p)+2c⁺ = 24	2
13	Aluminium	27·1	27		. . 3*	(4a+2p)+3c⁺ = 27	3
14	Silicon	28·3	28, 29, 30	4	. . . 4*	(4a)+2c⁺+2c⁻ = 28	0
15	Phosphorus	31·04	31	3*	1 . 3 4 5	?	
16	Sulphur	32·06	32, 34, 33	2*	. 2 . 4 . 6	(4a+2p)+2c⁻+4b = 32	0
17	Chlorine	35·46	35, 37	1*	1 . 3 . 5 . 7	(5a)+c⁻+6b = 35	0
18	Argon	39·88	40, 36			(9a+4p) = 40	4
19	Potassium	39·1	39, 41		1*	(9a+p)+b = 39	1
20	Calcium	40·07	40, 44		. 2*	(8a+2p)+2c⁺ = 40	2
21	Scandium	44·1	45		. 2 3*	(9a)+3c⁺ = 45	3
22	Titanium	48·1	48		. 2 3 4	(9a)+2c⁺+2c⁻ = 48	2
23	Vanadium	51·06	51		. 2 3* 4 5	(9a)+3c⁺+2c⁻ = 51	3
24	Chromium	52·0	52, 53		. 2 3* 4 . 6	(8a+2p)+3c⁺+3c⁻ = 52	3
25	Manganese	54·93	55		. 2* 3 4 . 6 7	(8a+2p)+3c⁺+4c⁻ = 55	3
26	Iron	55·84	56, 54		. 2 3* . . 6	(9a+2p)+3c⁺+3c⁻ = 56	3
27	Cobalt	58·97	59		. 2* 3 4	(11a)+3c⁺+2c⁻ = 59	3
28	Nickel	58·68	58, 60		. 2* 3	(11a+2p)+2c⁺+2c⁻ = 58	2
29	Copper	63·57	63, 65		1 2*	(14a+p)+c⁺+c⁻ = 63	3
30	Zinc	65·37	64, 66, 68, 70		. 2*	(14a+2p)+2c⁻ = 64	2
31	Gallium	69·9	69, 71		. . 3*	(15a)+2c⁺+c⁻ = 69	4
32	Germanium	72·5	74, 72, 70	4	. . . 4*	(15a)+2c⁺+2c⁻ = 72	4
33	Arsenic	74·96	75	3*	. 2 . 4 . 6	(15a)+3c⁻+2c⁺ = 75	4
34	Selenium	79·2	80, 78, 76, 82, 77, 74	2*	. 2 . 4 . 6	(15a)+2c⁻+4c⁺ = 78	6
35	Bromine	79·92	79, 81	1*	1 . 3 . 5 . 7	(14a+2p)+c⁻+6c⁺ = 79	8
36	Krypton	82·92	84, 86, 82, 83, 80, 78			(20a+4p) = 84	8
37	Rubidium	85·45	85, 87		1*	(20a+2p)+c⁺ = 85	7
38	Strontium	87·63	88, 86		. 2*	(20a+2p)+2c⁺ = 88	8

* "Principal" valency.
† From Haekh's *Chemical Encyclopædia*.

TABLE OF ELEMENTS—continued

Atomic Number	Element	Atomic Weights	Atomic Weights of Isotopes	Valencies† −	Valencies† +	"Alternative" Structures Units in brackets are inert		Free Electrons
39	Yttrium	89·0	89		. 2 3*	$(20a)+3c^+$	=89	7
40	Zirconium	90·6	90, 94, 92		. 2 3 4*	$(19a+2p)+4c^+$	=90	8
41	Niobium	93·5			. 2 3* 4 5	$(19a+2p)+3c^++2c^-$	=93	7
42	Molybdenum	96·0	98, 96, 95		. 2 3 4* 5 6	$(19a+2p)+4c^++2c^-$	=96	8
43	Masurium				. 2 3* 4 . 6 7	$(19a+2p)+3c^++4c^-$	=99	7
44	Ruthenium	101·7	102, 101, 104		. 2 3 4* . 6 7 8	$(19a+2p)+4c^++4c^-$	=102	8
45	Rhodium	102·9			. 2 3* 4 . 6	$(20a+2p)+3c^++4c^-$	=103	7
46	Palladium	106·7			2* . 4	$(23a+2p)+2c^++2c^-$	=106	8
47	Silver	107·88	107, 109		1* 2	$(25a+p)+c^++c^-$	=107	7
48	Cadmium	112·40	114, 112, 110, 113, 111, 116		. 2*	$(26a+2p)+2c^+$	=112	10
49	Indium	114·8	115		. . 3*	$(26a+2p)+3c^+$	=115	11
50	Tin	118·7	120, 118, 116, 124, 119, 117, 122	4	. 2 . 4*	$(26a+2p)+2c^++2c^-$	=118	10
51	Antimony	120·2	121, 123	3	. . 3 . 5*	$(26a+2p)+2c^++3c^-$	=121	10
52	Tellurium	127·5	128, 130, 126	2*	. . . 4 . 6	$(27a+2p)+2c^++4c^+$	=128	14
53	Iodine	126·92	127	1*	. . 3 . 5 . 7	$(26a+2p)+c^-+6c^+$	=127	14
54	Xenon	130·32	129, 132, 131, 134, 136, 128, 130			$(32a)$ =128, $(32a+2p)$ =130		12

Atomic Number	Element	Atomic Weights	Atomic Weights of Isotopes	Valencies† −	Valencies† +	"Alternative" Structures Units in brackets are inert		Free Electrons
55	Caesium	132·81	133		1*	$(32a+2p)+c^+$	=133	13
56	Barium	137·37	138, 137		. 2*	$(33a)+2c^+$	=138	14
57	Lanthanum	139·0	139		. 2 3*	$(32a+2p)+3c^+$	=139	15
58	Cerium	140·25	140, 142		. 2 3 4*	$(32a)+3c^++c^-$	=140	13
59	Praseodymium	140·6	141		. 2 3*	$(2c^-+c^+)$?		
60	Neodymium	144·3	142, 144, 146		. 2 3	,,		
61	Illinium				. 2 3	,,		
62	Samarium	150·4	152, 154, 151		. 2 3	,,		
63	Europium	152·0	151, 153		. 2 3	,,		
64	Gadolinium	157·3	155, 156, 157, 158		. 2 3	,,		
65	Terbium	159·2	159		. 2 3	,,		
66	Dysprosium	162·5	164, 162		. 2 3	,,		
67	Holmium	163·5	165		. 2 3	,,		
68	Erbium	167·4	164 to 176		. 2 3	,,		
69	Thulium	168·5	169		. 2 3	,,		
70	Ytterbium	173·5	174, 172, 173, 176		. 2 3	,,		
71	Lutecium	175·0	175		. 2 3	,,		
72	Hafnium	178·0			. 2 3 4*	$(41a+2p)+2c^++2c^-$	=178	18
73	Tantalum	181·5	181		. . 3 4 5*	$(41a+2p)+3c^++2c^-$	=181	19
74	Tungsten	184·0	184, 186, 182, 183		. 2 3 4* 5 6	$(41a+2p)+4c^++2c^-$	=184	20
75	Rhenium	187·7	187, 185		. 2 3 4 . 6 7	$(41a+2p)+4c^++3c^-$	=187	20
76	Osmium	190·9	192, 190, 189, 188		. 2 3 4* . 6 . 8	$(41a+2p)+4c^++4c^-$	=190	20
77	Iridium	193·1			. 2 3 4 . 6 7	$(43a)+4c^++3c^-$	=193	20
78	Platinum	195·2			. 2 . 4* . 6	$(44a+2p)+4c^++2c^-$	=196	22

* "Principal" valency.
† From Haekh's *Chemical Encyclopædia.*

TABLE OF ELEMENTS—continued

Atomic Number	Element	Atomic Weights	Atomic Weights of Isotopes	Valencies† −	Valencies† +	"Alternative" Structures Units in brackets are inert	Free Electrons
79	Gold	197·2			1 . 3 4	$(46a+2p)+3c^{+}+c^{-}$ =198	22
80	Mercury	200·6	202, 200, 199, 198, 201, 204		1 2*	$(48a+2p)+2c^{-}$ =200	20
81	Thallium	204·0			1* . 3 (RaC')	→$(47a+2p)+5d^{-}$ =210	20
82	Lead	207·2			. 2*. 4 (RaB)	→$(49a+2p)+4d^{-}$ =214	22
83	Bismuth	208·0	209		1 . 3*. 5 (RaC)	→$(50a+2p)+3d^{-}$ =214	22
84	Polonium	210·0			. 2 . 4 . 6 (RaA)	→$(52a+2p)+2d^{-}$ =218	24
85							
86	Radon	222·0			(Rn)	→$(55a+2p)$ =222	26
87							
88	Radium	226·0			. 2*	$(54a+2p)+2d^{+}$ =226	28
89	Actinium	227·0			. 2 3	$(53a+2p)+3d^{+}$ =226	28
90	Thorium	232·15			. 2 . 4*	$(54a)+4d^{+}$ =232	30
91	Protoactinium	230·0			. 2 3 . 5	$(53a+2p)+5d^{+}$ =234	32
92	Uranium	238·2			. 2 . 4 5 6*	$(53a+2p)+6d^{+}$ =238	34

* " Principal " valency.
† From Haekh's *Chemical Encyclopædia*.

PERIODIC CLASSIFICATION OF ELEMENTS

Group.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
Valency	+ 1	+ 2	+ 3	+ 4 / − 4	+ 5 / − 3	+ 6 / − 2	+ 7 / − 1	zero or 8
1	(1 H)						1 H	2 He
2	3 Li	4 Be	5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg	13 Al	14 Si	15 P	16 S	17 Cl	18 A
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe, 27 Co, 28 Ni
4	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Cb	42 Mo	43 Ma	44 Ru, 45 Rh, 46 Pd
5	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	57 La*	72 Hf	73 Ta	74 W	75 Re	76 Os, 77 Ir, 78 Pt
6	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 —	86 Rn
7	87 —	88 Ra	89 Ac	90 Th	91 Pa	92 U		

* With 58 Ce, 59 Pr, 60 Nd, 61 Il, 62 Sm, 63 Eu, 64 Gd, 65 Tb, 66 Dy, 67 Ho, 68 Er, 69 Tm, 70 Yb, 71 Lu.